UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MINNESOTA

REGENTS OF THE UNIVERSITY OF MINNESOTA Plaintiff, v. AT&T MOBILITY LLC, Defendant, ERICSSON, INC., and ALCATEL-LUCENT USA INC., Defendants-Intervenors.	Civil Action No. 0:14-cv-04666 JRT/TNL **JURY TRIAL DEMANDED**
REGENTS OF THE UNIVERSITY OF MINNESOTA Plaintiff. v. SPRINT SPECTRUM L.P., et al., Defendants, ERICSSON, INC., ALCATEL-LUCENT USA INC., and NOKIA SOLUTIONS AND NETWORKS US LLC, Defendants-Intervenors.	Civil Action No. 0:14-cv-04669 JRT/TNL **JURY TRIAL DEMANDED**

REGENTS OF THE UNIVERSITY OF MINNESOTA Plaintiff. v. T-MOBILE USA, INC., Defendant, ERICSSON, INC., ALCATEL-LUCENT USA INC., and NOKIA SOLUTIONS AND NETWORKS US LLC, Defendants-Intervenors.	Civil Action No. 0:14-cv-04671 JRT/TNL **JURY TRIAL DEMANDED**
REGENTS OF THE UNIVERSITY OF MINNESOTA Plaintiff. v. CELLCO PARTNERSHIP D/B/A ERICSSON WIRELESS, Defendant, ERICSSON, INC., and ALCATEL-LUCENT USA INC., Defendants-Intervenors.	Civil Action No. 0:14-cv-04672 JRT/TNL **JURY TRIAL DEMANDED**

DECLARATION AND DISCLOSURE OF OPINIONS OF
<u>DANIEL VAN DER WEIDE, PH.D. REGARDING CLAIM CONSTRUCTION</u>

I, Daniel van der Weide, Ph.D., declare as follows:

I. Introduction

1. My name is Dr. Daniel van der Weide. I have been retained by Ericsson, Inc., Nokia of America Corporation, Cellco Partnership, T-Mobile USA, Inc., Sprint Spectrum LP, and AT&T Mobility LLC (collectively, "Defendants").

2. I have been asked to review certain patents and related materials, and based upon that review to provide a background of the technology at issue in this lawsuit and to provide my expert opinion regarding certain issues in connection with claim construction.

3. I am over 18 years of age. Unless otherwise noted, the statements made herein are based on my personal knowledge, and if called to testify in Court, I could and would testify competently and truthfully with regard to this matter.

4. I am being compensated at my usual consulting rate of $550 per hour for my time spent on this matter. My compensation is not dependent on the outcome of this litigation or the testimony or opinions that I give.

5. My *curriculum vitae* and list of oral and written testimony are included in Exhibit B to this declaration.

6. My opinions and the basis for the conclusions I reached are fully discussed in later sections of this declaration.

7. In reaching these opinions and conclusions, I have relied upon my education, experience, and training, and my review of certain materials as explained below under "Materials Reviewed."

8. I reserve the right to supplement this declaration if further information becomes available or if I am asked to consider additional information. Furthermore, I reserve any right that I may have to consider and comment on any additional expert statements and testimony of any experts identified by Regents of the University of Minnesota ("Plaintiff"). I may also rely on demonstrative exhibits, beyond those contained in this declaration, to explain any future testimony or opinions.

A. Education and Experience

9. My education and experience are summarized in Exhibit B. I am a Full Professor in the Electrical and Computer Engineering Department of the University of Wisconsin-Madison. I obtained a Ph.D. in Electrical Engineering in 1993 from Stanford University. I received a Bachelor of Science in Electrical and Computer Engineering from the University of Iowa in 1988, where I also minored in Latin.

10. I was appointed a Full Professor in the Electrical and Computer Engineering Department of the University of Wisconsin-Madison in 2004. I have also received courtesy appointments in the Radiology, Biomedical Engineering, Physics and Materials Science Departments at the University of Wisconsin-Madison. I previously served as an Associate Professor in the University of Wisconsin-Madison Department of Electrical and Computer Engineering from 1999 to 2004. Before that, I served as both an Associate Professor and an Assistant Professor in the Electrical and Computer Engineering Department of the University of Delaware from 1995-1999. And from 1993 to 1995, I was a Post-Doctoral Researcher in the group of Klaus von Klitzing (Nobel Prize winner) at the Max Planck Institut für Festkörperforschung in Stuttgart, Germany.

11. I am the Founder and President of vdW Design, LLC, which specializes in design and consulting services for electrical measurements at high frequencies. I also have professional industry experience with high-frequency and lightwave communications systems and devices. For example, I co-founded Optametra LLC, to develop, build, sell and support coherent lightwave signal analyzers ("constellation analyzers"), which are both hardware and software systems to do vector signal analysis of communications systems in single-mode fiber based on complex modulation techniques like those discussed below; Optametra was acquired by Tektronix Inc. in 2011. I was also co-Founder, Board Member and Advisor for NeuWave Medical, Inc., which develops and sells microwave-based systems for percutaneous tissue ablation; NeuWave was acquired by Johnson & Johnson in 2016. In addition, I was the Founder and President of NFI, LLC, which develops devices relating to near-field imaging for skin cancer. I have also been involved with numerous other professional companies, starting companies in the areas of ultrawideband antennas and language training devices; and working for companies in microwave devices, cellular telephones, dye laser systems, and automatic testing equipment. Most recently I co-founded Elucent Medical Inc., which offers FDA-approved hardware and software to perform wireless surgical navigation for in breast and other organs.

12. I have also received extensive recognition for my work. I received the Vilas Associate Award, the Alexander von Humboldt Fellowship (which I postponed), and the PECASE Award from the National Science Foundation. I also received the Young Investigator Program Award from the Office of Naval Research. The DARPA ULTRA Program also awarded me with the Innovation/Technical Achievement Award. I also

received the University Research Award from the Ford Motor Company. Additionally, I received the Dean's Merit Increase and the Provost's Special Merit Increase from the University of Delaware. I was also a Teaching Fellow in a program at Stanford sponsored by the National Science Foundation.

13. I have performed extensive research, receiving over forty research grants. I have also supervised numerous post-doctoral researchers and doctoral candidates and graduates. Through my academic placements, I have extensive teaching experience, including in courses such as Applied Communication Systems, Advanced Communications Circuit Designs, Electromagnetic Wave Transmission, and others.

14. My work has also led to over one hundred journal publications, numerous book sections, over two hundred conference presentations, and over forty patents in the United States and abroad. I have recently performed NSF-sponsored research in wireless networking at the physical layer ("WiMi: A Reconfigurable Platform for Millimeter-Wave Wireless Networking and Sensing").

B. Materials Reviewed

15. As part of preparing this declaration, I have read U.S. Patent Nos. 7,251,768 ("the '768 patent"), RE45,230 ("the '230 patent"), 8,774,309 ("the '309 patent"), 8,718,815 ("the '815 patent"), and 8,588,317 ("the '317 patent"). I have also reviewed the prosecution histories for these patents and the documents cited in this declaration, as well as any other documents identified in Exhibit C.

16. I have reviewed the parties' proposed constructions and evidence disclosed in the parties' Joint Claim Construction Chart associated with these claim construction

proceedings. If the parties alter those constructions or identify additional material after this declaration is submitted, I may, if appropriate and permitted, submit a supplemental declaration addressing any new constructions.

C. Level of Ordinary Skill in the Art

17. I have been asked to offer my opinion regarding the level of ordinary skill in the art with respect to each of the Asserted Patents.

18. In my opinion, a person of ordinary skill in the art at the time the filing of U.S. Patents 7,251,768 and RE45,230 and their parent and provisional applications (approximately 2002-2013) would have a Master of Science in Electrical Engineering or a related field and at least two years of experience with the design or development of wireless communications systems. Additional experience in the design or development of wireless communications systems can substitute for less or differing education and vice-versa.

19. In my opinion, a person of ordinary skill in the art at the time the filing of U.S. Patents 8,774,309, 8,718,185, and 8,588,317 and their parent and provisional applications (approximately 2003-2013) would have a Bachelor of Science in Electrical Engineering or a related field and at least two years of experience with the design or development of wireless communications systems. Additional experience in the design or development of wireless communications systems can substitute for less or differing education and vice-versa.

D. Scope of Opinions

20. I understand the parties have provided agreed upon construction of certain terms in the claims of the Asserted Patents. A list of those agreed upon constructions is attached as Exhibit D.

21. I have been asked to provide my opinions regarding the meaning of certain disputed claim terms as understood by one of ordinary skill at the time of the invention. I understand that Plaintiff has asserted that conception date for the ’230 and ’768 patents is no later than March 8, 2001, and has asserted that the conception date for the ’317, ’185, and ’309 patents is no later than March 24, 2003. For my analysis, I will take these dates as the respective conception dates. My opinions as to these terms are based on my understanding of what the disputed claim terms are, and the evidence identified by the parties, as of the time that I executed this declaration.

II. Legal Standards Relied Upon

22. Certain legal principles that relate to my opinions have been explained to me.

23. I have been informed that ultimately the Court will determine how the terms will be construed. The intent of this declaration is to help inform the Court how a person of ordinary skill in the art would understand the meaning of certain disputed claim terms in the context of the Asserted Patents’ claims, specification, prosecution history, and knowledge of the technology, in a manner that will assist the Court in the process of finding a proper set of constructions.

24. It is my understanding from my discussions with counsel that terms found in a patent claim should, in general, be given their plain and ordinary meaning, as a person of

ordinary skill in the art would understand them. I understand that the claims themselves provide substantial guidance as to the meaning of particular terms, and the content of the surrounding words of the claim must be considered in determining the ordinary and customary meaning of those terms. Further, it is my understanding that a patentee can decide to act as their own lexicographer by explicitly defining terms to have specific meaning within the bounds of the patent specification. Finally, it is my understanding that statements made to the patent office by the patentee or their legal representative during prosecution can serve to illuminate the proper scope of claim terms and such statements must be considered in determining the appropriate claim construction.

25. I am informed from my discussions with counsel that, when construing a patent claim, the focus should be on the patent's intrinsic record, which consists of the claim language itself, the patent's written description and figures, and the prosecution file history. I further understand that courts should resort to extrinsic evidence, such as technical dictionaries or textbooks, only when the intrinsic record does not provide adequate guidance to construe the claim. I understand that claim terms are generally given their ordinary and customary meanings as understood by a person of ordinary skill in the art when read in the context of the specification and prosecution history.

26. In determining the meaning of the claims, I have followed my ordinary practice for claim construction: I endeavor to give a claim term the meaning that one of skill in the art, at the time of the invention and in light of the patent's specification and prosecution history, would have given it, except in two unusual circumstances: (1) where the intrinsic record provides a special definition for the term; or (2) where the patentee

disclaims a portion of the term's ordinary meaning. I understand that the intrinsic record may reveal a special definition given to a claim term by the inventor that differs from the meaning it would otherwise possess, and in such cases, the inventor's lexicography governs. I also understand that the specification may reveal an intentional disclaimer or disavowal of claim scope by the inventor.

27. I am informed by counsel that, under 35 U.S.C. § 112, ¶ 2, a patent must particularly point out and distinctly claim the subject matter which the applicants regarded as the alleged invention. I understand that a claim is indefinite if an element of that claim, read in light of the patent's specification and prosecution history, fails to inform, with reasonable certainty, those skilled in the art at the time of the earliest priority date of the patent, what the scope of the claimed invention is.

28. I understand from my discussions with counsel that when a term of degree or subjective term is used in a claim, then the claim, when read in light of the specification and the prosecution history, must provide objective boundaries for those of skill in the art in determining the meaning of the term. The scope of the patent claim language cannot depend solely on the subjective opinion of a particular individual.

III. Technology Tutorial[1]

A. The Linear Precoding Patents ('768 and '230 patents)

29. Communicating is fundamental to human existence. Over distances greater than a voice will carry, we have developed technologies for telecommunications, as simple and early as smoke signals, progressing through gestures (*e.g.*, semaphore flags), the telegraph, telephone, and wireless networks. Modern telecommunication technology sends messages via a signal (carried by radio waves), which will encounter many obstacles before reaching the receiver. For example, the signal may bounce off buildings and cars, or be partially absorbed by walls and trees. By the time the signal reaches the receiver, it may have changed dramatically. Below I discuss various commonly used techniques taken by the transmitter to make it easier for the receiver to reconstruct the message that was intended to be received.

30. Telecommunication happens through a channel, which is an abstraction of the path taken by the signal from sender to recipient. Examples of channels include wire (*e.g.*, landline telephone), optical fiber (long-distance networking), and air (wireless). Like a channel for water flow, a communications channel has a finite capacity: there is a limit on the data rate for error-free transmission. Sending a few love-notes on folded paper boats along a small canal would have little error if the boats were few and far between, but to send a novel, with each page on a separate boat, in the same amount of time, the canal would become clogged with boats, some might not arrive or arrive out of order and the

[1] All the concepts that I have described in my Technology Tutorial section were well known prior to the alleged invention dates of the '768, '230, '317, '185, and '309 patents.

result is therefore likely to be garbled. As I discuss below, there is a fundamental limit to the capacity of a channel, which depends on the bandwidth (range of frequency available) and signal-to-noise ratio.

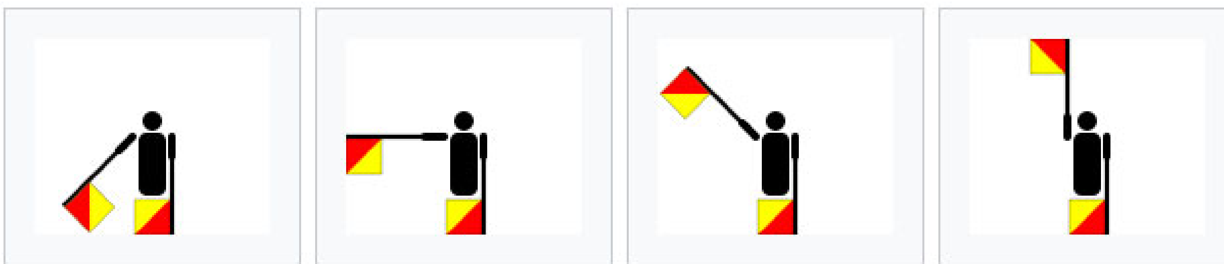
31. Despite using a highly variable channel filled with obstructions, wireless communication has become ubiquitous in modern society. The ease of use at the endpoints (*e.g.*, the laptop or mobile phone) masks the complexity of the system that connects them.

1. Communication Using Wireless Signals

32. Modern wireless networks allow us to send and receive many different types of information, commonly referred to as "data." For example, we can connect to the internet, stream music, download videos, speak to each other on a phone call, and send e-mails. All data, whether it be a friend's voice on the other end of the phone line or an e-mail, is transmitted and received in "binary form," that is, digitally, in 1s and 0s. For example, if you are on a phone call and speak into your phone's microphone, the phone will convert your speech to a series of 1s and 0s and then send those 1s and 0s to the person on the other end of the phone call. The phone receiving the 1s and 0s will then convert the 1s and 0s back into speech and output the speech through the receiving phone's speaker. It is critical that the receiving phone correctly receive as many of the 1s and 0s as possible so that it can interpret the intended message.

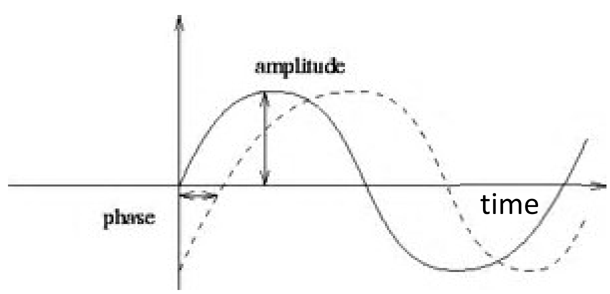
33. These 1s and 0s are transmitted over the air by electromagnetic waves, called carrier waves. By changing (modulating) the characteristics of the carrier wave, the transmitter can indicate whether it is sending a 1, a 0, or certain combinations of 1s and 0s. This type of communication has been around for centuries, albeit in a simpler form. For

example, communicating with carrier waves is like communication with smoke signals. To communicate with smoke signals, the sender and receiver must agree on a code beforehand. For example, the code might provide that one puff of smoke means "yes" and two puffs of smoke mean "no." A richer type of coded visual communication is via flag semaphores. Flag semaphores convey information at a distance by means of visual signals with hand-held flags. As with smoke signals, the sender and receiver must use a predetermined code to communicate. For example, the sender and receiver might agree on the following signals to communicate the letters A, B, C, or D, or the numbers 1, 2, 3, or 4:



A or 1 B or 2 C or 3 D or 4

34. In modern wireless communications systems, we communicate by modulating carrier waves. One cycle of a carrier wave vs time is abstracted below:



35. The wave has three characteristics: the amplitude (height), the phase (*e.g.*, relative time difference between the dashed wave and the solid wave), and the frequency (how many cycles occur in one second). To communicate information, the transmitter

changes the amplitude, phase, or frequency, sometimes in combination. As is the case with smoke signals and flag semaphores, the transmitter and receiver agree on a predetermined meaning for each change in the wave characteristic, i.e., how the wave is modulated. For example, the transmitter and receiver may agree that a large amplitude represents a 1 and a small amplitude represents a 0. Alternatively, both the amplitude and the phase can be modified to send information. This allows the transmitter to communicate multiple bits with one signal. For example, the transmitter and receiver might agree upon the following mapping of bits to wave characteristics:

Amplitude	**Phase change**	**Meaning**
Large	Small	11
Large	Large	10
Small	Small	01
Small	Large	00

36. By increasing the granularity of the agreed code for modulation, that is, by specifying many different combinations of phases and amplitudes—such combinations are known as "constellation symbols" or just "symbols"—the transmitter can send many bits per symbol. This increase in bits per symbol is not, however, without cost: higher signal-to-noise ratios (i.e., the strength of the signal as compared to the background noise caused by environmental conditions) at the receiver are required to distinguish among symbols encoded with finer granularity.

2. Modifying Wireless Signals to Ensure Reception

37. As explained above, when a transmitter sends a signal to a receiver, the signal will likely encounter many obstructions before it is received. For example, the signal may

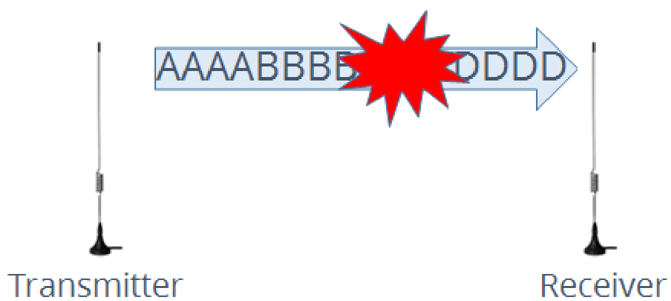
be reflected from buildings and cars, or be partially absorbed by walls and trees. These obstructions will destroy or modify the signal, making it difficult for the receiver to interpret the received signal and to determine the originally transmitted signal. Modern transmitters use various well-known techniques to modify the signal before transmission to overcome these challenges. Such techniques include error-control coding, interleaving, modulation mapping, linear precoding, and symbol interleaving.

38. **Error control coding**: Generally, error-control coding adds redundancy (extra bits) by sending the same data multiple times in multiple ways. One commonly used type of error control code is a "convolutional code." Convolutional codes generally send the same information up to three times in three different configurations.

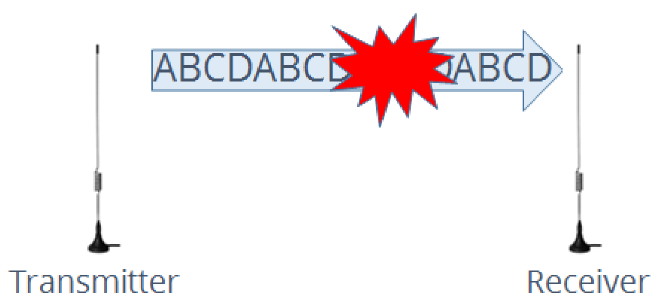
39. **Interleaving:** "Interleaving" spreads apart adjacent bits or symbols to make it more likely for the receiver to reconstruct received data. Interleaving may spread bits or symbols apart in time to avoid burst errors. Alternatively, interleaving may spread symbols apart in frequency to avoid interference that affects adjacent symbols.

40. Interleaving in time is performed prior to mapping (the next step in the signal processing chain described below), and is used to overcome short-term noise or interference that destroy parts of a signal before it reaches the receiver. The loss of several adjacent bits is called a "burst." Because a burst error is a string of adjacent bits in error, it is far costlier than a single bit error. Adjacent bits are often closely related to each other, so the loss of both of those bits is harder for the receiver to recover from than the loss of just one of those bits. The purpose of interleaving is to mitigate the effects of these bursts by reordering the bits so that previously adjacent bits (or symbols) are separated. *See* '768

patent at 4:62-64 ("interleaver **14** separates the coded bits c so that mapping unit **16** maps neighboring bits to different constellation symbols ..."). Take for example, a transmitter sending the symbols "A," "B," "C," and "D," to a receiver. To ensure the symbols arrive at the receiver, the transmitter sends each one four times. If the transmitter sends "AAAABBBBCCCCDDDD" and the message experiences a burst error, the receiver may never receive one of the symbols, such as the letter "C" in the example below:



41. But if the transmitter interleaves the symbols to transmit "ABCDABCDABCDABCD," the receiver will receive all four letters, as shown below:



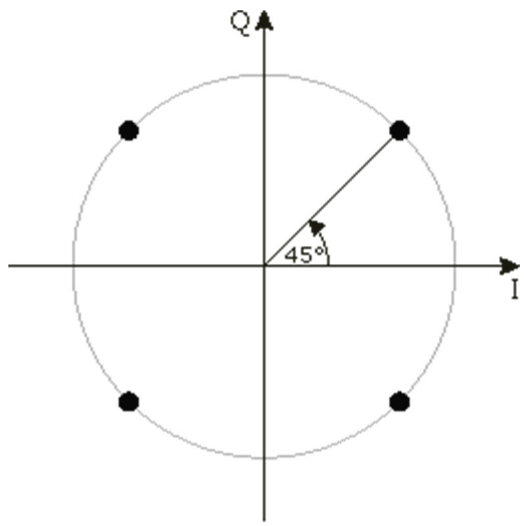
42. Interleaving in frequency is performed after mapping (the next step in the signal processing chain described below), and is used to overcome interference that affects symbols that are adjacent to each other in frequency. As is the case with the adjacent bits described above, adjacent symbols input into this interleaver are closely related to each other. For example, in the context of the '768 and '230 patents, the symbols input into this

type of interleaver have been linearly precoded by the linear precoder (described below). The linear precoder combines input constellation symbols with each other, providing new precoded symbols at the output. Each of the precoded symbols, which is a combination of constellation symbols, is input into the interleaver. In context, the receiver can recover from the loss of a constellation symbol as long as it receives just one of these precoded symbols. Because these precoded symbols are combinations of the same two constellation symbols, they are closely related to each other, and it is desirable to spread them apart so that they are not destroyed by the same fade.

43. Fading is a type of interference common to the wireless channel that acts over a frequency range called the "coherence bandwidth." The coherence bandwidth is the frequency range over which two signals could interfere with each other. Such closely related signals could also be vulnerable to cancellation from a third interfering signal. Like interleaving in time, interleaving in frequency separates symbols that are adjacent in frequency to ensure that two adjacent symbols, which are likely closely correlated (related to each other), are not destroyed by the same fade.

44. **Mapping:** After bits have been error-control coded and interleaved (in time, not in frequency), they may be translated (modulated), or "mapped," to different analog signal characteristics called symbols. As mentioned above, wireless devices do not send 1s and 0s through the air, but rather waveforms that represent 1s and 0s. As described above, by changing the characteristics of a wave, such as its phase or amplitude, the transmitter can indicate whether it is sending a 1, a 0, or some combination of 1s and 0s. As with flag semaphores, the transmitter and receiver must agree beforehand which symbol corresponds

to a given set of bits. For example, the transmitter and receiver may agree that a first symbol—a combination of amplitude and phase—represents the bits "00" and a second (different) combination of amplitude and phase represent the bits "11." The symbols available to the transmitter are typically depicted on a constellation diagram, as shown below:



QPSK constellation

45. The above diagram depicts a quadrature phase-shift keying "QPSK" constellation that consists of 4 possible constellation symbols[2]. Each of the four points on this diagram represents a different phase. The phase is represented by the angle relative to the horizontal axis (here, 45°) and the (constant) amplitude is represented by the distance from the center of the diagram to the constellation point. To transmit data, the transmitter must pick one of these four constellation points, or put otherwise, "map" the bits to one of these constellation symbols. See '768 patent at 4:36-37 ("Mapping unit **16** maps the

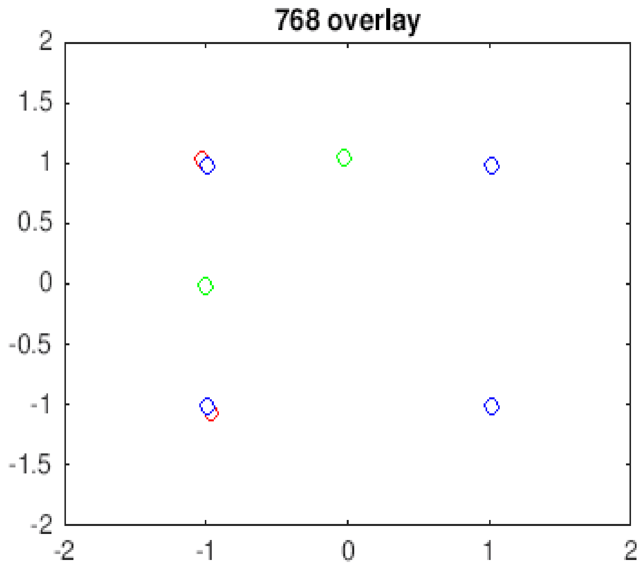
[2] By convention, a cosine wave is the "in-phase" or "I" reference; a sine wave is 90° out of phase with a cosine, and would be plotted on the "quadrature" or "Q" axis of the constellation diagram, sometimes called an "I-Q" diagram.

symbols d to constellation symbols s."). For example, to represent the bits "11", the transmitter may map the bits "11" to the constellation symbol in the lower left-hand corner.

46. **Linear Precoding**: In the context of the patents-in-suit, the transmitter uses a "precoder" to perform a mathematical operation, called a "linear transformation," on the input constellation symbols. The precoder takes constellation symbols and performs a linear transformation on them to output new symbols called "precoded symbols." In some embodiments, the precoded symbols are not "restricted to the finite alphabet of the constellation." *See* '768 patent, claim 1. That is, the precoded symbols are not restricted to the symbols used in the mapping unit (the symbol set from which they originated), but rather can appear anywhere else on that constellation diagram. For example, the "finite alphabet of the constellation" in the figure above consists of the four possible symbols shown in black dots.

47. In the example below, I selected two constellation symbols (shown in red) from a constellation having four symbols ("the finite alphabet of the constellation" shown in blue[3]). I applied the 2×2 linear precoding matrix that appears in the '768 patent at 7:15 to the (input) red symbols to create (output) precoded symbols shown in green. As can be seen on the diagram below, the precoded constellation symbols in green do not fall on one of the four original (blue) constellation symbols, thus the output of the precoder is not limited to the input alphabet of the constellation.

[3] To make the selected red symbols distinct from the original alphabet (blue), I added a small amount of noise.



48. Precoding is used to achieve "signal space diversity." This concept is explained by Boutros,[4] cited by both the '768 and '230 patents. Boutros teaches that precoding of the constellation symbols achieves signal space diversity, which can make the transmitted constellation more robust to interference; this is analogous to the purpose of interleaving discussed above. The form of precoding described in Boutros is a "symbol rotation."

49. Figure 1 from Boutros appears below:

[4] J. Boutros and E. Viterbo, "Signal Space Diversity: A Power-and Bandwidth-Efficient Diversity Technique for the Rayleigh Fading Channel," IEEE Transactions on Information Theory, vol. 44, No.4, pp. 1453-1467, Jul. 1998.

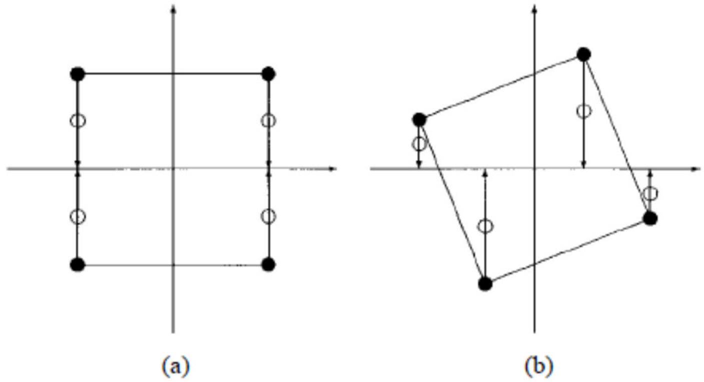


Fig. 1. How to increase diversity: (a) $L = 1$ and (b) $L = 2$.

50. Figure 1(a) depicts a constellation without precoding. Figure 1(b) depicts a constellation that has been precoded, i.e., the precoder has rotated the constellation of symbols counterclockwise by some angle via a linear transformation called a rotation matrix. The purpose of rotating the constellation is to help mitigate the effects of fading.

51. Fading, or destructive interference, may act on only part of the symbol space. In the figures above, the fade acts on only the vertical axis, causing the constellation symbols to collapse toward the horizontal axis. The four solid dots represent the constellation symbols before experiencing a fade. The four open dots on Figure 1(a) represent the constellation symbols collapsing towards the horizontal axis (note the arrows pointing toward the horizontal axis, showing the direction of collapse). If the fade causes the constellation symbols to completely collapse to the horizontal axis, the original four constellation symbols degenerate into two symbols, indistinguishable to the receiver. This is like a typewriter overstriking the letter ‘a’ with ‘e’; you cannot distinguish which letter was intended, since both occupy the same space.

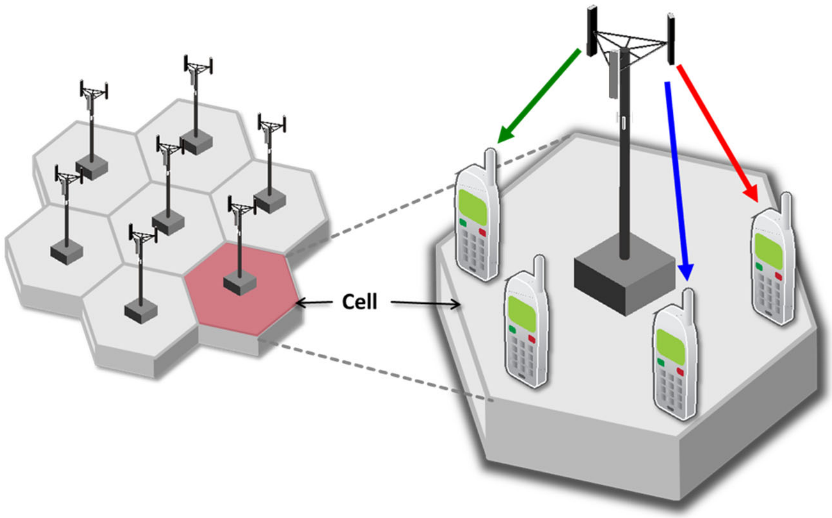
52. If the constellation is rotated, as shown in Figure 1(b), even if the constellation symbols collapse towards the horizontal axis (as shown by the four empty dots in Figure 1(b)), the symbols on each side would no longer overlap. This rotation thus lifts the degeneracy of the collapsed symbols, and it enables the receiver to distinguish between the four constellation symbols despite the severe fade.

53. The transmitter and receiver previously agree on the linear transformation used, so when the receiver receives the precoded symbol, it reverses the linear transformation to derive the original constellation symbols, *e.g.,* in the case of rotation, by +30 degrees, the constellation is rotated by -30 degrees to reverse the linear transformation. Thus, a linear transformation of the constellation, such as a rotation, is a way of precoding the constellation to make it more robust against fading.

B. The Carrier Frequency Offset Patents (the ’309, ’185, and ’317 patents)

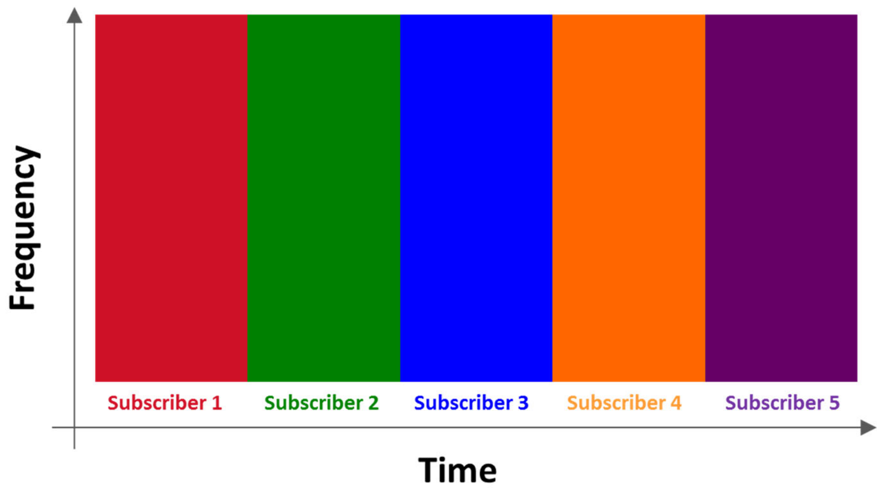
1. Communications at Different Times

54. In cellular communications systems, multiple handsets communicate with a single transmitting and receiving station called a base station.



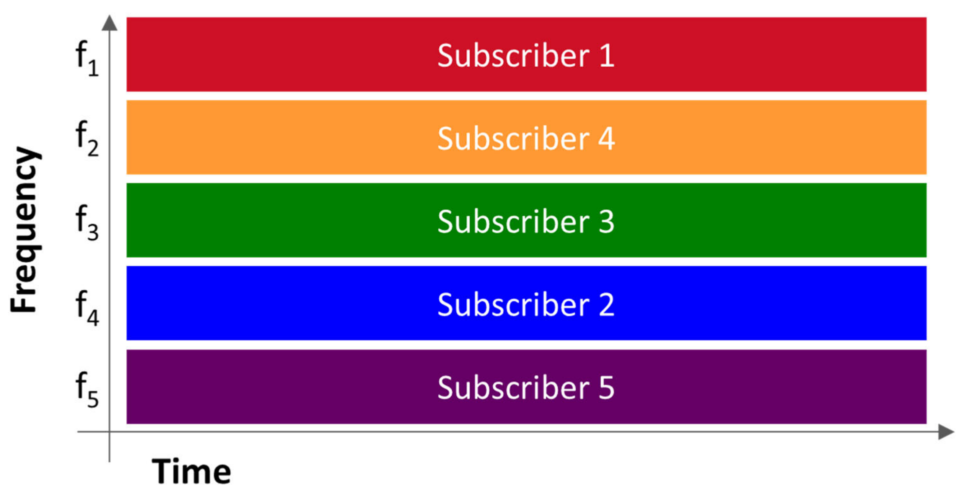
55. In contrast to ordinary broadcast radio, which is a one-way transmission from the transmitters to the receivers, in cellular communication systems each handset is in two-way communication with the base station. Since there are many handsets in a cellular communication system, they need to communicate with the base station without causing or experiencing interference from the other handsets. One method known in the field for doing so is to schedule each handset with a particular slice of time in which it can communicate.

56. This is called time division multiple access ("TDMA") because time is being divided to allow multiple handsets to access the base station. As illustrated below, each handset (*i.e.*, subscriber) communicates at a specific time, but over the entire available frequency channel.



2. Communications at Different Frequencies

57. Time division multiple access is limited, though, because as more and more users attempt to communicate with the base station, their time allocations become less and less frequent and/or their time slices become thinner, all of which reduces their data rates. It thus became apparent that multiple handsets needed to communicate with the base station at the same time. One way developed, prior to the patents at issue here, was to make it possible for the users to communicate with the base station on different frequencies.



58. This technique is called frequency division multiple access ("FDMA") because the frequencies are divided to allow multiple users to access the base station. As shown above, each handset can communicate at any time with the base station, since each uses a different frequency (frequency f1 through f5 for subscribers 1 through 5). However, this technique limits data rates, because the bandwidth for an individual user is a fraction of what was available to a single user under TDMA.

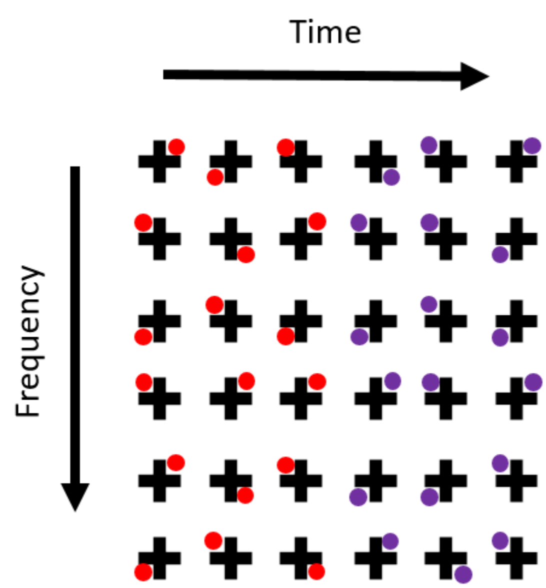
3. Combining Time and Frequency

59. Neither TDMA (time division) nor FDMA (frequency division) is ideal by itself; therefore, many communication systems prior to the patents at issue here combined these two techniques: allowing users to transmit on certain frequencies only at certain times. By slicing the time allocations and frequency allocations finely, the system can provide a very flexible allocation of resources to the handsets. Therefore, handsets that need a significant amount of data and resources at a certain time can get them, while not shutting out those that need fewer resources in the moment.

60. The time/frequency allocations can be presented in a grid, with time on one axis and frequency on another. The close packing of symbols in frequency is accomplished through numerical modulation and filtering of orthogonal functions, *e.g.*, sines and cosines, known as subcarriers. "Orthogonal" means that each subcarrier in the set is linearly independent from the others, so that each can be filtered and processed without the result corrupting the others. This is known to one of skill as orthogonal frequency division

multiplexing (OFDM)[5], and its roots can be traced back to the late 1950's as well as to U.S. Patent No. 3,488,445 (filed Nov. 14, 1966).

61. A simple example of OFDM[6] is illustrated in the following figure, with the crosses indicating the constellation axes[7], while the red and purple dots[8] indicate the symbol (or data value in the parlance of the Carrier Frequency Offset patents) in that constellation to be transmitted; each symbol represents two bits. In this exemplary figure, each member of a set of subcarriers (a "block") is one column having six elements, in total representing 6×2=12 bits, since each subcarrier is bearing data.



[5] Yiyan Wu and W. Y. Zou, "Orthogonal frequency division multiplexing: a multi-carrier modulation scheme," in IEEE Transactions on Consumer Electronics, vol. 41, no. 3, pp. 392-399, Aug. 1995.

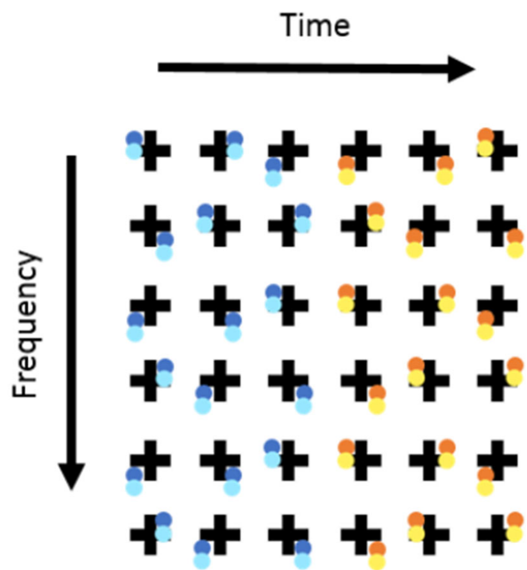
[6] The figure depicts columnar blocks of symbols prior to transforming them into a time-domain output.

[7] For a detailed explanation of constellations, see Paragraphs 39-56.

[8] The dots are different colors for purely illustrative purposes.

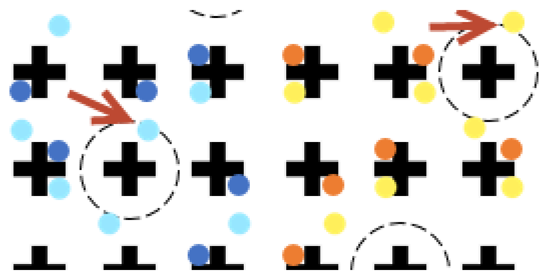
4. Carrier Frequency Offsets

62. Because the OFDM subcarriers are orthogonal, they are permitted to overlap with each other in frequency, since the frequency spectrum of any given subcarrier has zero amplitude at the frequencies of every other subcarrier. This is only true, however, if the frequencies of both transmitter and receiver are *identical*. This is seldom the case in practice. Usually there is an offset between them, meaning the symbols shift frequencies from what was transmitted, and what is received, and errors will occur in analyzing the transmitted data because orthogonality among the subcarriers breaks down. In contrast to the (red/purple) symbols in the transmitted symbols above, the figure below illustrates the received symbols (dark blue and orange dots) and the received, but frequency-*offset* symbols, added in lighter colors (light blue and yellow). This frequency offset can occur when the transmitter has a constant carrier frequency shift, which may occur if the transmitter's local oscillator frequency does not match that of the receiver's, or if the receiver is experiencing the Doppler effect as it moves relative to the transmitter. This "carrier frequency offset" (CFO) causes the received symbols to be misaligned, with their energy starting to leak into the space of adjacent subcarriers. This would result in errors, if not otherwise accounted for, as the frequency-offset symbols could not be properly decoded.



63. One way to address this problem (taught by some of the named inventors of the Carrier Frequency Offset patents in a prior-art publication[9] subsequently referred to as "Ma et al.") is to leave certain strategic elements in this time-frequency grid empty, *i.e.*, not to transmit any data symbols at different subcarriers in sequential blocks. In the figure below, some dashed circles are intended to be empty, with no symbols (data). In the case of CFO, some adjacent symbol data can nonetheless be identified within the dashed circles (as indicated by the red arrows). If the receiver knows that these circles should be empty, then it can deduce that there is CFO. The receiver will also know how to compensate for that frequency shift, because it knows the frequency spacing. Ma et al. describe a "cost function" whose value should be zero if there is no CFO, but whose value is non-zero if there is CFO.

[9] Xiaoli Ma, C. Tepedelenlioglu, G. B. Giannakis and S. Barbarossa, "Non-data-aided carrier offset estimators for OFDM with null subcarriers: identifiability, algorithms, and performance," in IEEE Journal on Selected Areas in Communications, vol. 19, no. 12, pp. 2504-2515, Dec 2001.



5. MIMO

64. Prior art systems utilize "MIMO," or "multiple-input multiple-output," a form of transmission that employs multiple antennas at both the transmitter and receiver to increase transmission speed and reduce interference.

65. In a MIMO system, the data stream to be sent is separated into independent, different signals, which are sent through an array of antennas at the transmitter and subsequently travel through many paths in space to reach the array of antennas at the receiver. Upon reception, compensation for channel effects and reassembly of the independent signals, the data stream is reproduced. In a single-output transmitter, on the other hand, the transmitted signal does not combine with any different transmitted signals because only one signal is sent. Thus, the enhanced data capacity due to multiple (different) transmitted signals–a hallmark of MIMO–is necessary to the invention described in the CFO Patents. In the SISO (prior art) case—single-input single-output—it is only necessary to view the single transmission to determine that content. In MIMO, however, as mentioned above, **__all__** the transmitted signals must be analyzed to determine the cumulative signal content.

66. MIMO may be combined with prior art wireless communication schemes, such as OFDM.

IV. Disputed Claim Terms for the Linear Precoding Patents[10]

67. In the discussion that follows, each term is presented below along with my understanding of the positions being articulated by the parties and the claim from amongst the asserted claims in which the term appears.

[10] I understand that Plaintiff is currently asserting claims 1, 8, 9, 11, 13, 17-18, and 21 of the ’768 patent, and claims 1–3, 13, 16–17, 30, 33–34, 36, 42–46, 49-50, 56, 58, 64-65, 68-69, 72, and 77 of the ’230 patent.

A. "a precoder that applies a liner [sic] transformation to the constellation symbols to produce precoded symbols" ('768 patent cl. 1) / "a precoder that linearly precodes the constellation symbols" ('768 patent cl. 13) / "linearly precoding the constellation symbols by applying a linear transformation to produce precoded symbols" ('768 patent cl. 21)

Defendants Construction	Plaintiff Construction
"a precoder that applies a linear transformation to combine two or more of the constellation symbols with each other to produce precoded symbols, wherein the linear transformation has the following properties: 1) For any constellation symbols a and b, f(a + b) = f(a) + f(b) 2) For any scalar k, f(k*a) = k*f(a)"	"a precoder that applies…": a precoder that applies a linear transformation that transforms a block of input symbols into a block of output symbols in which each output symbol is a linear combination, or weighted sum, of input symbols. "linear transformation": a mathematical operation on vectors f(x), which has the property that for any vectors a and b that are valid arguments to f, f(a + b) = f(a) + f(b), and for any scalar k f(k*a) = k*f(a). The linear transformation does not include the operation of using a spreading sequence of chips to spread each information-bearing symbol over a set of data symbols. "a precoder that linearly precodes…": see proposed construction for the phrase "a precoder that applies…" "linearly precoding…": applying a linear transformation that transforms a block of input symbols in a block of output symbols in which each output symbol is a linear combination, or weighted sum, of input symbols.

68. It is my opinion that a person of ordinary skill in the art at the time of the patents reading the claims would have understood these related terms to mean:

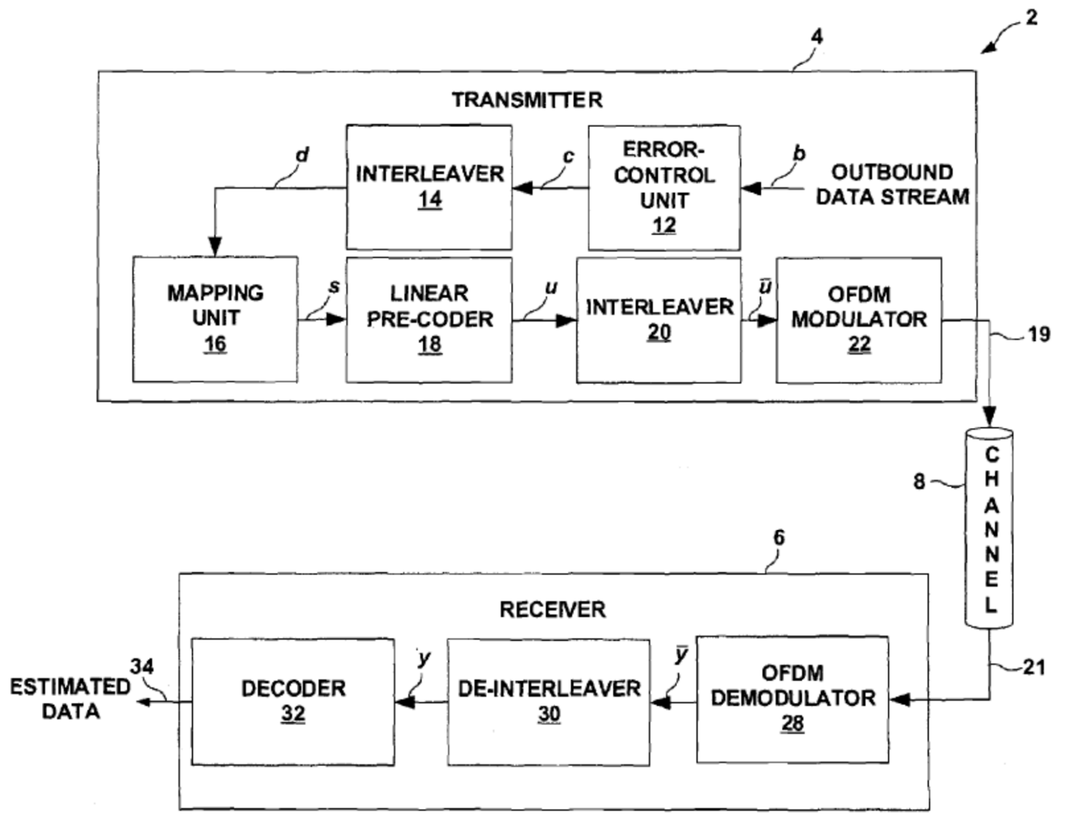
"a precoder that applies a linear transformation to combine two or more of the constellation symbols with each other to produce precoded symbols, wherein the linear transformation has the following properties:

1) For any constellation symbols a and b, f(a+b) = f(a) + f(b)
2) For any scalar k, f(k*a) = k*f(a)"

69. A person of ordinary skill in the art would not agree with Plaintiff's construction for at least three reasons. First, the claimed linear transformation must be applied to "the constellation symbols" and not any "block of input symbols." Second, the parties agree that the claims expressly require the application of a ***linear*** transformation, yet only Defendants' construction is consistent with this transformation actually being linear. Third, spreading sequences would not be excluded from the claimed linear transformations.

70. First, a person of ordinary skill in the art reading claims 1, 13, and 21 in light of the specification and file history would understand that the claimed linear transformation must be applied to "the constellation symbols," which are produced by the prior mapping function or step in the claims. This understanding is supported by the '768 specification. For example, the '768 specification states, "[m]apping unit **16** maps the symbols d to constellation symbols s" ['768 patent at 4:36-37] and "[a]fter constellation mapping, linear pre-coder **18** processes successive blocks of M symbols…" ['768 patent at 4:44-45]. The "blocks of M symbols" are comprised only of constellation symbols from mapping unit **16** depicted in Fig. 1 of the '768:

FIG. 1



71. During prosecution, Applicants explained that "the input symbols provided to the precoder" are "the constellation symbols output by the constellation mapping unit." *See, e.g.*, File History of the '768 patent at 164. A person of ordinary skill in the art would understand that this sentence means that the claimed "linear transformation" operates on the "constellation symbols" generated by the mapping function or step in claims 1, 13, and 21.

72. Second, as noted, the parties agree that the claims expressly require the application of a ***linear*** transformation. Because Plaintiff's proposal allows the claimed linear transformation to be applied to any "block of input symbols," it encompasses situations wherein the output of the constellation mapping unit is put through a ***non-linear***

transformation before being fed to the linear transformation. The combination of a non-linear operation with a linear operation can be, collectively, a non-linear operation. In other words, the resulting combined transformation applied to "the constellation symbols" can be non-linear.

73. Further, Plaintiff's construction construes the term a "linear transformation" as being "a linear combination ***or weighted sum***." However, a "weighted sum" is *not* always a linear transformation. Weighted sums can be non-linear, such as in the case of a "weighted sum of squares" operation. As described by National Institute of Science and Technology (NIST), a weighted sum of squares comprises squaring the input (a non-linear transformation) and then combining the squares (a linear transformation). National Institute of Science and Technology, *WEIGHTED SUM OF SQUARES*, http://www.itl.nist.gov/div898/software/dataplot/refman2/auxillar/weigsmsq.htm (last visited March 15, 2017). Overall, this transformation is non-linear. Other examples of non-linear transformations that could be combined with a linear transformation to create a "weighted sum" include taking the logarithm and taking the real or imaginary part of a complex value. *See, e.g.,* T. Nagy, (Weighted) Sum of 'n' Correlated Lognormals: Probability Density Function –Numerical calculation, (describing a weighted sum of lognormals, which is also a non-linear operation resulting in a "weighted sum").

74. Third, a person of ordinary skill in the art would understand that spreading sequences can be linear transformations and thus should not be excluded from the scope of the claims.

75. A spreading sequence is a code (a sequence of numbers) that is unique to parties communicating via an electronic communication system. Spreading sequences, for example, enable base stations[11] to communicate with multiple users over the same frequency. For example, a base station may assign unique spreading sequences to users A and B, and it communicates to each user its unique spreading sequence. The base station then applies the spreading sequences assigned to user A to a signal intended for user A and the spreading sequence assigned to user B to a signal intended for user B. The base station can now send both signals on the same frequency at the same time. Normally, these signals would interfere; because of the unique spreading sequences, however, user A will only be able to decode the signal intended for user A and user B will only be able to decode the signal intended for user B.

76. A Hadamard transform is one example where spreading sequences satisfy the agreed upon properties of a linear transformation. A Hadamard transform is comprised of particular spreading sequences (Walsh sequences) that can ensure signals intended for each user, such as the signals intended for users A and B in the example above, do not interfere with each other, i.e., they are orthogonal. A person of ordinary skill in the art

[11] As I briefly described in ¶ 57, a "base station" is a part of a wireless communication network that acts as a hub between two cellular devices, such as a router in the case of home internet, or part of a cellular tower in a cellular communications system. When cellular user A calls cellular user B, the phones do not connect directly to each other. Rather, cellular user A sends a signal to the nearest base station. The signal is then routed through the cellular network to the base station nearest to cellular user B. The base station nearest to cellular user B then transmits the signal to cellular user B.

understands that such spreading sequences make up Hadamard transforms, which are linear transformations.

77. As taught by Ahmed and Rao[12] (p. 100): "Walsh-Hadamard transforms…are analogs of the discrete Fourier transform (DFT)." An FFT matrix is a type of discrete Fourier transform. Akansu and Haddad[13] define a 2×2 Walsh Hadamard transform as follows (p.59):

> The matrix obtained by ordering the rows by their sequency is the discrete Walsh transform. These are shown in Fig. 2.7(e). There are other representations as well, the most notable is the Hadamard form. These matrices of order $N = 2^p$ are defined recursively:

$$\boxed{H_1 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}}$$

$$H_{2N} = \frac{1}{\sqrt{2}}\begin{bmatrix} H_N & H_N \\ H_N & -H_N \end{bmatrix} = H_1 \otimes H_N \tag{2.168}$$

(red box added, indicating the 2×2 Hadamard transform).

78. As I have cited above, this Hadamard matrix satisfies the agreed-upon properties of a linear transformation. Thus, a person of ordinary skill in the art would have understood that this matrix represents a linear transformation. One of ordinary skill in the art would have understood that such Hadamard transforms are within the scope of the claimed linear transformation, and that the plain meaning of linear transformation does not exclude spreading sequences. The provisional application 60/374,933 (incorporated by reference by the '768 patent at 1:5–12), "Optimal Transmitter Eigen-Beamforming and

[12] Ahmed and Rao "Orthogonal Transforms for Digital Signal Processing" (Springer 1975)

[13] Ali N. Akansu and Richard A. Haddad, Chapter 2 - Orthogonal Transforms, in "Multiresolution Signal Decomposition" (Academic Press 1992).

Space Time Block Coding Based on Partial Channel State Information," indicates that the inventors considered spreading sequences to be within the scope of the invention, at least because they equated a spreading code matrix with a precoder: "…[E]ach information-bearing symbol s(i) is first spread by the code…of length P to obtain the chip sequence…" (p. 5). "…[W]e define…P x N_t ***spreading code matrix*** C …" "[1]The spreading matrix C can be viewed (and will be invariably referred to) as a precoder, or, as a beamformer." (p. 6) (emphasis added).

79. Therefore, a person of ordinary skill in the art would understand that spreading sequences can fall within the scope of the claims.

B. "interleaved data stream" ('768 cls. 1, 13 and 21) / "a symbol interleaver to process the precoded [symbols/data stream] to produce permuted blocks of the precoded symbols" ('768 cls. 1, 13) / "processing the [sic: precoded] symbols to produce permuted blocks of [sic: precoded] symbols" ('768 cl. 21) / "a deinterleaver that reassembles blocks of linearly precoded symbols from the demodulated data stream" ('768 cl. 8) / "an interleaver that interleaves the encoded symbols to produce interleaved symbols" ('230 cl. 1) / "interleaving the coded bits to produce interleaved bits" ('230 cl. 49) / "interleaving the coded symbols to produce interleaved symbols" ('230 cls. 13 and 16)

Defendants	**Plaintiff**
interleaved data stream: "bits that are the same as the bits of the encoded data stream that have been reordered so that adjacent bits are separated"	**interleaved data stream:** a data stream that is generated using an interleaver, which is an electronic circuit or computer implemented algorithm that takes an ordered set of values and reorders them"
a symbol interleaver to process the precoded [symbols/data stream] to produce permuted blocks of the precoded symbols: "an electronic circuit or computer-implemented algorithm that takes the precoded symbols and reorders them to separate adjacent symbols"	**a symbol interleaver to process the precoded [symbols/data stream] to produce permuted blocks of the precoded symbols:** "an electronic circuit or computer-implemented algorithm that takes an ordered set of precoded symbols and reorders them."

processing the [sic: precoded] symbols to produce permuted blocks of [sic: precoded] symbols: "taking the precoded symbols and reordering them to separate adjacent symbols"	**processing the [sic: precoded] symbols to produce permuted blocks of [sic: precoded] symbols:** "processing an ordered set of precoded symbols and reordering them"
a deinterleaver that reassembles blocks of linearly precoded symbols from the demodulated data stream: "an electronic circuit or computer-implemented algorithm that takes the demodulated data stream and reassembles blocks of linearly precoded symbols that had been reordered to separate adjacent symbols"	**a deinterleaver that reassembles blocks of linearly precoded symbols from the demodulated data stream:** "an electronic circuit or computer implemented algorithm that rearranges received demodulated data values corresponding to transmitted precoded symbols to reverse an interleaving step applied to the precoded symbols"
an interleaver that interleaves the encoded symbols to produce interleaved symbols: "an electronic circuit or computer-implemented algorithm that takes the encoded symbols and reorders them to separate adjacent symbols"	**an interleaver that interleaves the encoded symbols to produce interleaved symbols:** "an electronic circuit or computer-implemented algorithm that takes an ordered set of encoded symbols and reorders them"
interleaving the coded bits to produce interleaved bits: "taking the coded bits and reordering them to separate adjacent bits"	**interleaving the coded bits to produce interleaved bits:** "taking an ordered set of coded symbols and reordering them"
interleaving the coded symbols to produce interleaved symbols: "taking the coded symbols and reordering them to separate adjacent symbols"	**interleaving the coded symbols to produce interleaved symbols:** "taking an ordered set of coded bits and reordering them"

80. It is my opinion that a person of ordinary skill in the art at the time of the patents reading the claims would have understood the various "interleaved" / "interleaver" / "interleaving" terms listed above consistent with Defendants' proposed constructions. It is also my opinion that one of skill would not agree with Plaintiff's construction because that person would understand that interleaving requires (1) the bits/symbols input into the interleaver to retain their identity, and (2) separating adjacent bits/symbols, as compared to their positions pre-interleaving.

81. As explained above, interleaving may spread bits or symbols apart in time to avoid burst errors, or, alternatively, interleaving may spread symbols apart in frequency to avoid interference that affects adjacent symbols. In either case, one of skill in the art would recognize that interleaving requires retaining the identity of the bits/symbols being interleaved and separating adjacent bits/symbols, as compared to their positions pre-interleaving. That is, the explanations below apply equally whether a claim limitation references interleaving in time or interleaving in frequency.

82. First, those skilled in the art would recognize that interleaving requires the separation of every adjacent bit/symbol, as compared to their positions pre-interleaving. The extrinsic evidence cited by both sides confirms that interleavers reorder bits/symbols so that adjacent bits/symbols are separated. For example, Plaintiff cited the widely-used dictionary "Newton's Telecommunications Dictionary."[14] This dictionary explains that interleaving is performed "to reduce the number of undetected error bursts," and provides that "[i]n the interleaving process, code symbols are reordered before transmission in such a manner that any two successive code symbols are separated by [L]-1 symbols in the transmitted sequence, where [L] is called the degree of interleaving." A person of ordinary skill would recognize that the degree of interleaving 'l' is much greater than one. For example, the '768 patent specification explains that "consecutive input bits" are spread by "a distance of at least M in the output stream," where M is greater than the size of an OFDM symbol. '768 patent at 5:5-10. The other extrinsic evidence cited by the parties is consistent

[14] H. Newton, H Newton's Telecom Dictionary, p. 415, (19th ed. 2003).

in this regard. *See* Data & Telecommunications Dictionary[15] at 395 (interleaving for data transmission means "code symbols are arranged in an interleaved pattern before transmission and reassembled upon receipt").

83. Moreover, Baltersee explains that the purpose of interleaving is to "transform[] [a] bursty channel into an independently distributed channel." Baltersee at 2358. In other words, as explained in detail above, the purpose of interleaving is to distribute adjacent bits across the channel in time so that if a burst occurs, adjacent bits are not lost. Therefore, the adjacent bits of the claimed "encoded data stream," for instance, must be separated in the "interleaved data stream," as Defendants' construction states.

84. In my opinion, one of skill would understand Plaintiff's construction to be overly broad, because "reorder[ing]" of bits/symbols does not guarantee that they are no longer adjacent. For example, Plaintiff's construction, which calls merely for "reordering," would encompass an algorithm that just reverses the message "AAAABBBBCCCCDDDD" to read "DDDDCCCCBBBBAAAA." The reversed message "DDDDCCCCBBBBAAAA" would be no less vulnerable to burst errors than the original message "AAAABBBBCCCCDDDD." As shown below, a single burst error could destroy every transmission of the letter B, as was the case for the original message (shown in the technology tutorial above):

[15] J. K. Peterson, Data & Telecommunications Dictionary, p. 395, CRC Press, (1999).

85. In my opinion, a POSITA would not consider Plaintiff's construction to be interleaving.

86. Additionally, the term "interleaving," as used by a POSITA, is the reordering of bits/symbols ***while maintaining*** the identity of each bit/symbol—i.e., a 0 at the input remains 0 at the output, and 1 remains 1. For example, Plaintiff's extrinsic support for this term discloses that an interleaver "takes symbols from an [sic] fixed alphabet as the input ***and produces the identical symbols at the output in a different temporal order***." Andrews at 1 (emphasis added); *see also* ECF No. 190-1 at 6. The IBM Dictionary similarly provides that "interleave" means "to arrange parts of one sequence of things or events so that they alternate with parts of one or more other sequences of the same nature and ***so that each sequence retains its identity***." IBM Dictionary[16] at 351 (emphasis added). The IEEE Dictionary similarly provides that to "interleave" means "to arrange parts of one sequence of things or events so that they alternate with parts of one or more other sequences of things or events ***so that each sequence retains its identity.***" IEEE Dictionary at 577. Caire[17]

[16] McDaniel, G. and International Business Machines Corporation. (1994). IBM dictionary of computing. New York, McGraw-Hill.

[17] Caire et al., "Bit-Interleaved Coded Modulation," IEEE Transactions on Information Theory, vol. 44, No. 3 (May 1998).

confirms there is a "one-to-one" correspondence between the bits before and after interleaving, meaning that bit interleaving does not change the values of the bits. Caire at 2.

87. By contrast, a person of ordinary skill would not understand Plaintiff's proposal as interleaving because it does not require that the claimed interleaver maintain the integrity of the original value of the bits. One of skill would appreciate that Plaintiff's proposal expands the function of, for example, the claimed "bit interleaver" to cover completely different functions, such as "scrambling." The purpose of scrambling is not to separate bits for temporal diversity, but rather, for example, to provide security or change spectral content by actually changing the values of the data stream, not merely reshuffling bits or symbols so that they are no longer adjacent. Unlike interleaving, which consists of rearranging bits so that adjacent bits are separated, scrambling obscures a message by, among other things, reordering the bits in any fashion and even changing the identities of some or all of the bits, e.g., changing bits from a 1 to a 0. A person of ordinary skill in the art would consider scrambling and interleaving to be separate and distinct functions, and would understand that Plaintiff's construction obscures those critical differences.

88. A common type of interleaver called a periodic interleaver is described in Bahai and Saltzberg[18]:

[18] Bahai, A. R. S., & Saltzberg, B. R. "Multi-Carrier Digital Communications: Theory and Applications of OFDM" (Kluwer Academic Publishers 1999).

than the sub-carrier spacing will lead to correlated errors among the sub-carriers.

The performance of codes in the presence of bursts can be improved by the process of interleaving. Rather than operating on symbols that are adjacent in time and/or frequency, the code is made to operate on symbols with sufficient spacing so that the errors are more independent. A simple and common form of interleaving is periodic interleaving illustrated in Figure 7.4. At the receiver, the symbols are de-interleaved before decoding. The decoder therefore operates on symbols spaced *m* symbol periods apart as transmitted. The spacing can be in time, frequency, or both.

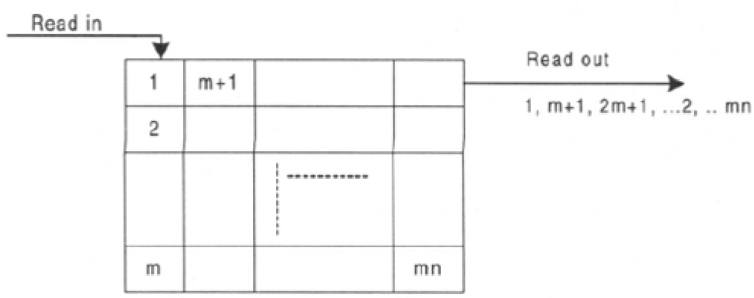


Figure 7.4. Implementation of periodic interleaving.

89. As shown in the figure above, symbols are read sequentially into a table. The first symbols 1 through m will be read into the leftmost column of the table. The symbols are then read into the next column to the right, and so on. An example table is shown below:

1	9	17	25
2	10	18	26
3	11	19	27
4	12	20	28
5	13	21	29

6	14	22	30
7	15	23	31
8	16	24	32

90. To complete the process of interleaving, the symbols are read out of the table row-wise (horizontally). For the example above, the output of the interleaver would be 1, 9, 17, 25, 2, 10, 18, 26, 3, 11… As is shown from the output, every adjacent symbol at the input has been separated, *i.e.*, the output read row-wise is no longer an integer sequence.

91. Finally, one of skill would understand that Plaintiff's proposed constructions also read out important claim requirements. For instance, Plaintiff's construction improperly reads out the claim requirement that the symbol interleaver process "***the*** precoded symbols" i.e., the symbols generated by the claimed precoder. Instead, Plaintiff's construction calls for operating on "***an*** ordered set of precoded symbols." Plaintiff's use of "an" would allow for any arbitrary ordered set of precoded symbols to be interleaved, whereas a person of ordinary skill would understand that Defendants' construction is more consistent with the claim language by limiting the processing to "the precoded symbols." This error is present in each of Plaintiff's proposed constructions for the "interleaved" / "interleaver" / "interleaving" terms listed above.

C. "applying/applies a linear transformation to a/the stream of information bearing symbols" ('230 patent cls. 1, 16, 49, 64, 68)

Defendants Construction	Plaintiff Construction
"applies/applying a time invariant linear transformation to the stream of information bearing symbols by combining two or more of the information bearing symbols with each other to produce precoded symbols, wherein the linear transformation has the following properties: 1) For any constellation symbols a and b, f(a + b) = f(a) + f(b) 2) For any scalar k, f(k*a) = k*f(a)"	"transforms/transforming blocks of symbols from the stream of information bearing symbols using a linear transformation to produce symbols that linear combinations, or weighted sums, of the information bearing symbols." "linear transformation": *see* proposed construction for the '768 patent

92. It is my opinion that a person of ordinary skill in the art at the time of the patents reading the claims would have understood these claim elements to mean "applies/applying a time invariant linear transformation to the stream of information bearing symbols by combining two or more of the information bearing symbols with each other to produce precoded symbols, wherein the linear transformation has the following properties: (1) For any constellation symbols a and b, f(a +b)= f(a) + f(b); (2) For any scalar k, f(k*a) = k*f(a)."

93. A transformation is "time invariant" if the transformation does not vary as a function of time. That is, if the transformation remains the same over time, it is time invariant. If the transformation changes over time, it is time varying. For example, the linear transformation $y(x)=2 * x$ is time invariant because, at all times, y will equal $2 * x$.

By contrast, the linear transformation *y(x)*=2 * *x* * *t*, where *t* is an indication of time (*e.g.*, in seconds), varies with time based on the variable *t* and is therefore "time varying."[19]

94. A person of ordinary skill in the art reading the '230 patent claims in light of the specification understands that the linear transformation of the claimed invention, Θ, ***excludes*** time-varying linear transformations:

> "The encoder Θ considered here does not depend on the OFDM symbol index i. ***Time-varying encoder may be useful for certain purposes***, (e.g., power loading)***, but they will not be pursued here.*** Hence, from now on, we will drop our OFDM symbol index i for brevity."

'230 patent at 5:25-30 (emphasis added); *see also* CoC at 9. Thus, the claimed linear transformation must be time invariant.

95. The remainder of the '230 patent describes only time-invariant linear transformations. The matrix Θ is referenced more than 80 times after the disclaimer, and not once does it include the time variable index "i" when represented as an equation, or does the specification otherwise indicate that Θ can vary over time.

96. Furthermore, a person of ordinary skill in the art would have recognized that there was considerable technical benefit in choosing to limit the linear transformations in the invention to linear transformations that are time-invariant as opposed to time-varying. Specifying a transformation as being time-invariant enables the powerful concept of superposition, *i.e.*, the ability to analyze a complex system by decomposing it into elementary constituents. Being able to decompose a complex system into constituent

[19] One of ordinary skill in the art would recognize the "*" symbol to signify multiplication in the context of defining a linear function as in the proposed claim constructions; one of skill also understands that the proximity of, *e.g.,* "2" and "*x*" likewise stands for multiplication.

elements enables a level of analysis of the communication system that may otherwise not be possible. For example, this analysis facilitates optimizing parameters of the communication system to, *e.g.*, enhance the system's resilience in certain environments. Thus, the limitation to time invariant transformations was more than a mere convenience; a person of ordinary skill in the art would have understood that the limitation provided benefits to the claimed invention.

97. Beyond the exclusion of time-invariant transformations, the other differences between the parties' constructions for these terms relate generally to the meaning of "linear transformation." With respect to these differences, my analysis in Section IV.B applies equally here.

D. "[wherein the] linear transformation is based on multiple matrices…[]" ('230 patent cls. 30, 33, 43, 64, 68) / "wherein the linear transformation is based on: $\Theta = F_{N_t}^{T} \mathrm{diag}(1, \alpha, \ldots, \alpha^{N_t - 1})$, $\alpha := {}^{j 2\pi/P}$" ('230 patent cls. 41, 66, 70)

Claim Limitation	Defendants Construction	Plaintiff Construction
"[wherein the] linear transformation is based on multiple matrices [comprising]…[]"	Indefinite.	"The linear transformation can be described as multiplication by a matrix that is the product of at least two other matrices"
"wherein the linear transformation is based on: $\Theta = F_{N_t}^{T} \mathrm{diag}(1, \alpha, \ldots, \alpha^{N_t - 1})$, $\alpha := e^{j2\pi/P}$"	Indefinite.	The linear transformation includes a mathematical operation that can be described as multiplication by the matrix Θ as specified in the claim.

98. In my opinion, a person of ordinary skill in the art at the time of the patents reading the claims would not be able to determine with reasonable certainty what

mathematical operations fall within the scope of the claimed matrices. In my opinion, one of skill would find that neither the claims nor the intrinsic record provides any objective standard for determining how much deviation from the claimed matrices is allowed. The specification sets forth one example of a linear transformation where the equation Θ is used to calculate the linear transformation.

99. For example, claim 41 of the ’230 patent requires that the precoder apply a linear transformation “based on” matrix Θ, as follows:

> *41. The method of claim 40, wherein the number of the antennas is represented by N_t, wherein the first matrix is based on an N_t-point inverse version of the FFT matrix, wherein the linear transformation is based on:*
>
> $$\Theta = F_{N_t}^T \operatorname{diag}(1, \alpha, \ldots, \alpha^{N_t-1}),\ \alpha := e^{j2\pi/P}$$
>
> *wherein $F_{N_t}^T$ represents the first matrix, and wherein*
> *$\operatorname{diag}(1, \alpha, \ldots, \alpha^{N_t-1})$*
> *represents the second matrix, wherein P is an integer.*

(highlighting added). This equation in claim 41 specifies a linear transformation “based on” Θ using a particular variable, α, which is defined as $\alpha := e^{j\underline{\mathbf{2}}\pi/P}$. A person of ordinary skill in the art would not be able to determine with reasonable certainty in view of the specification and the prosecution history, the degree to which α can differ from the claimed equation and still fall within the scope of the claim. For example, α could be modified so that there is an eight in the exponent instead of a two, $\alpha := e^{j\underline{\mathbf{8}}\pi/P}$, so that it is negative, $\alpha := \mathbf{-}e^{j2\pi/P}$, so that the exponent is negative, $\alpha := e^{-j2\pi/P}$, or so that alpha varies over time, $\alpha := e^{j2\pi\underline{\mathbf{i}}/P}$. Similarly, the first matrix could be modified so that it is not a

transpose matrix. These would represent different equations that would provide different results, and with any of these changes to Θ, one of skill in the art would not be able to determine with reasonable certainty whether the claimed linear transformation is "based on" the claimed equation.

100. In my opinion, a person of ordinary skill in the art would find no support in the '230 patent for Plaintiff's constructions, which defines "based on" as "***includes*** a mathematical operation that ***can be described as*** multiplication by the matrix Θ." The specification provides no objective standard for determining whether an operation "can be described as" the multiplication specified in Plaintiff's constructions. Nor could a person of ordinary skill in the art make such a determination with reasonable certainty for the same reasons described for "based on," *i.e.*, a person of ordinary skill in the art would not know how similar a multiplication by a matrix would have to be to a multiplication by the matrix Θ for it to fall within the scope of Plaintiff's construction. It is also not sufficiently clear who is doing the "describing," or how similar an operation must be to the specified multiplication to be permissibly "described." Moreover, by using the word "includes," one of skill would understand that Plaintiff's constructions can include additional, unspecified operations, further obscuring the boundaries of Plaintiff's proposed constructions.

E. "wherein the first matrix is based on a fast Fourier transform (FFT) matrix, and wherein the second matrix is based on a diagonal matrix" ('230 patent cls. 30, 64, 68) / "wherein the first matrix is a matrix of size

N_txN_t…wherein the second matrix is a diagonal matrix" ('230 patent cl. 30, 64, 68)

Claim Limitation	Defendants Construction	Plaintiff Construction
"wherein the first matrix is based on a fast Fourier transform (FFT) matrix, and wherein the second matrix is based on a diagonal matrix" [cls. 30, 40, 64, 68]	The term "based on" is indefinite. Should the court find this term to not be indefinite, the linear transformation must be represented in the following order: [FFT matrix]* [Diagonal matrix]	Ordinary meaning
"wherein the first matrix is a matrix of size N_txN_t… wherein the second matrix is a diagonal matrix" [cl. 33]	The term "based on" in the prior limitation of this claim is indefinite. Should the court find this term to not be indefinite, the linear transformation must be represented in the following order: [first matrix of size N_t rows by N_t columns, wherein each entry of the first matrix is based on a power of $e^{j2\pi/Nt}$, each entry of a column of the first matrix being equal to one,]*[second matrix that is a diagonal matrix of size N_txN_t having diagonal entries that are based respectively on different powers of $e^{j2\pi/p}$ including the zeroth power, wherein P is a positive integer]	The first matrix is a matrix with Nt rows and Nt columns, where Nt is the number of transmit antennas in the transmitter. The second matrix is a diagonal matrix.

101. It is my opinion that a person of ordinary skill in the art would not be able to determine with reasonable certainty what mathematical operations fall within the scope of

the claim. In my opinion, neither any asserted claim nor the intrinsic record informs a person of ordinary skill in the art what it means for one matrix to be "based on" another matrix.

102. For instance, a "diagonal matrix" is "a matrix having non-zero values only on the diagonal," such as the following:

$$\begin{matrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{matrix}$$

Without any objective standard in the claims or specification, a person of ordinary skill in the art would not be able to determine with reasonable certainty the degree to which a matrix can differ from this diagonal matrix and still be "based on" it.

103. For example, a person of ordinary skill in the art would not know with reasonable certainty whether the following matrix, which adds one non-zero value outside the diagonal (in red), falls within the scope of the claim:

$$\begin{matrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 1 \end{matrix}$$

Alternatively, the matrix may be a tridiagonal matrix, which is a matrix that has nonzero elements on the main diagonal, as well as on the diagonals above and below the main diagonal (as shown in red above and blue below), as in the following example:

$$\begin{matrix} 1 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 1 \end{matrix}$$

104. The specification does not provide an objective standard for determining whether these other matrices are "based on" a diagonal matrix.

105. In the event the Court determines these claims are not indefinite, a person of ordinary skill in the art would have understood that the claimed matrices must appear in the recited order. In general, matrix multiplication is not commutative; the product of two matrices is dependent upon the order in which the matrices are multiplied: A*B (A times B) does not necessarily equal B*A (B times A).

106. Further, to a person of ordinary skill in the art, a mathematical expression is read from left to right. If a mathematical expression includes matrices identified as the "first" and "second," it would be understood that the "first" matrix appears first and the "second" matrix appears second. Thus, in a matrix multiplication, one skilled in the art would recognize a "first" matrix to refer to the matrix on the left and a "second" matrix to refer to the matrix on the right. By contrast, one skilled in the art would *not* refer to the right-hand matrix as the "first" matrix or the left-hand matrix as the "second" matrix. This understanding is important, since reversing the order of matrices in a multiplication may provide a different result.

107. Additionally, I have reviewed the citations that Plaintiff provided in support of its construction, ECF No. 298-1 at 7, and the only disclosure of the matrix multiplication is the equation that I have annotated below. This equation places the "first matrix" (the FFT matrix or matrix of size $N_t x N_t$) on the left and the "second matrix" (the diagonal matrix) on the right, as follows:

$$\Theta = \underbrace{\boxed{F_{N_t}^T}}_{\text{"First"}} \underbrace{\boxed{\operatorname{diag}(1, \alpha, \ldots, \alpha^{N_t - 1})}}_{\text{"Second"}}, \qquad \alpha := e^{j2\pi/P}$$

108. *See* Provisional App. No. 60/374,935 at 47 (annotated), 59 (same); CoC at 6 (same). This is further confirmed by claims 41, 66, and 70 of the ’230 patent, which depend on claims 40, 64, and 68 at issue here. These claims cite the same equation for Θ and refer to $F_{N_t}^T$, situated on the left side of the multiplication, as the “first” matrix and *diag*(1, α,..., α^{N_t-1}), situated on the right side of the multiplication, as the “second” matrix. Thus, in my opinion, a person of ordinary skill in the art reading the claims and specification would understand that the multiplication must be carried out in the following order: [“first matrix”] * [“second matrix”].

F. “applying a unitary matrix” (’230 patent cls. 3, 46, 56)

Defendants Construction	Plaintiff Construction
“performing a mathematical operation that, when expressed in its matrix form, is multiplication by a unitary matrix”	“Performing a mathematical operation that, when expressed in matrix form, includes multiplication with at least a unitary matrix”

109. I understand that the parties have agreed that a “unitary matrix” is “a square matrix whose conjugate transpose is equal to its inverse.” I agree that a person of ordinary skill in the art would consider this a proper definition for “unitary matrix.” The meaning of “a square matrix whose conjugate transpose is equal to its inverse” is that, for any unitary matrix *U*, multiplying *U* by its conjugate transpose, *U**, yields the identity matrix. The

identity matrix is generally denoted as I. Thus, it can be written that $UU^* = I$. Additionally, a matrix multiplied by the identity matrix is itself. This means that, for a matrix A, $AI = A$.

110. A person of ordinary skill in the art would not agree with Plaintiff's proposal because it would include any mathematical operation. For example, consider a system that multiplies two non-unitary matrices, A and B. One of ordinary skill in the art would recognize that this operation, AB, would not fall within the scope of the term at issue, "applying a unitary matrix," because the operation is a multiplication of purely non-unitary matrices. However, because of the mathematical properties of a unitary matrix described above, AB is the mathematical equivalent of ABUU* (which equals ABI, which equals AB). Thus, virtually any operation would fall within Plaintiff's construction.

111. In my opinion, Defendants' construction is how a person of ordinary skill in the art would understand this term because it requires that the actual precoding algorithm must, when written in its matrix form, be multiplication by a unitary matrix. Thus, using the example above, Defendants' construction makes clear that AB cannot be arbitrarily manipulated to ABUU* to satisfy the limitation.

G. "a diagonal matrix to phase-rotate each entry of a symbol vector" ('230 patent cls. 30, 64, 68)

Defendants Construction	Plaintiff Construction
Indefinite	"a diagonal matrix that applies a set of phase offsets to the entries of a symbol vector, such as diag1, α, …, αNt-1, to modify the phase of at least some of those symbols"

112. This term calls for a diagonal matrix to phase rotate each entry of a symbol vector. First, as background, a diagonal matrix is a matrix that has non-zero values only along the diagonal from upper-left to lower-right, as in the example below:

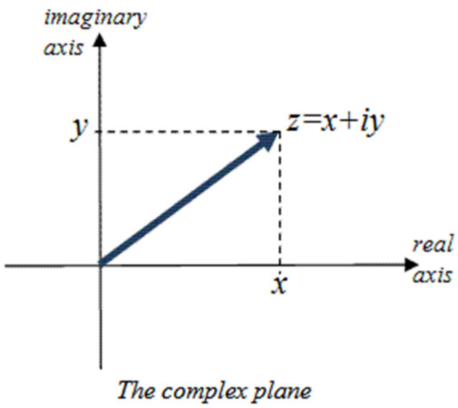
$$\begin{matrix} A & 0 & 0 \\ 0 & B & 0 \\ 0 & 0 & C \end{matrix}$$

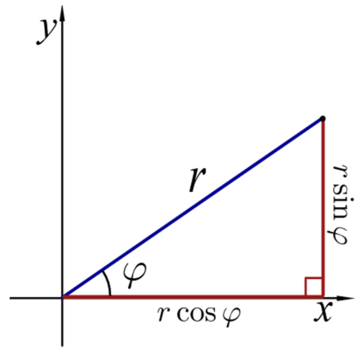
This exemplary matrix has the variables A, B, and C on the diagonal, and can be expressed as *diag(A,B,C)*. Multiplying a diagonal matrix by a vector multiplies each of the terms of the vector by the corresponding diagonal entry—first entry in the vector by first entry in the matrix, second entry in the vector by second entry in the matrix, and so on. For example, referring again to the matrix above, multiplying *diag(A,B,C)* by a vector $\begin{bmatrix} x \\ y \\ z \end{bmatrix}$ yields vector $\begin{bmatrix} Ax \\ By \\ Cz \end{bmatrix}$.

113. Next, with respect to phase-rotation, it first must be understood that every complex number can be represented as a point in the two-plane complex plane—with the one axis (x) representing the real component, and the other axis (y) representing the imaginary component of the complex number. Complex numbers are thus defined by the coordinates of the real and imaginary components, and are typically expressed in one of two forms—the latter of which is called polar form:

- $z = x + iy$, or
- $z = r(\cos \varphi + i \sin \varphi)$, where "*r*" is the polar magnitude, and φ, the angular coordinate from a reference direction (below, the positive x axis).

The two figures below demonstrate both forms of expressing complex numbers.





With respect to the polar form, the angular component, *φ,* is often referred to as the complex number's "phase," *i.e.,* angle with respect to the positive *x* (real) axis.

114. Relevant to this discussion is that when multiplying two numbers expressed in polar form, a POSTIA would understand that one can simply multiply the polar magnitudes and add the polar angles (phases) to arrive at the product. For example, (5∠5°)(2∠20°) = 10∠25°. As another example, (5∠5°)(2∠0°) = 10∠5°. In this way, one of skill would understand that multiplying one complex by another will result in a phase "rotation"—e.g., from 5° to 25°. On the other hand, one of skill would know that multiplying a complex number by a number with 0° phase (*i.e.*, a real number), will not produce any phase rotation—i.e., the complex number will keep its same phase as before.

115. Turning back to the claim term at issue, claim 30 of the '230 patent requires the diagonal matrix to "phase-rotate each entry of a symbol vector." This necessarily means that each entry in the diagonal matrix must be a complex number in order to "rotate" its corresponding entry. Nevertheless, claim 31, which depends from claim 30, reads as follows:

> *31. The wireless communication device of claim 30, wherein the number of the antennas is represented by N_t, wherein the first matrix is based on an N_t-point inverse version of the FFT matrix, wherein the linear transformation is based on:*
>
> $$\Theta = \mathbf{F}_{N_t}^T \operatorname{diag}(1, \alpha, \ldots, \alpha^{N_t - 1}), \ \alpha := e^{j2\pi/P}$$

Here, the diagonal matrix includes an entry that is a real number—"1". Because "1" is a real number, it will not phase rotate its corresponding entry in the symbol vector as one of ordinary skill would understand that term. (Indeed, the "1" will not change the symbol entry's magnitude, either.)

116. In relevant part, the '230 patent specification includes a similar inconsistency. The patent does not define "phase" or "phase rotation," and only even mentions these concepts within the brief disclosure below.

> LCP-B provides a construction of unitary precoders for any number of transmit-antennas $N_t \in \mathbb{N}$:
>
> $$\Theta = \mathbf{F}_{N_t}^T diag(1, \alpha, \ldots, \alpha^{N_t - 1}), \quad \alpha := e^{j2\pi/P}$$
>
> where $P \in \mathbb{N}$, and $\mathbf{F}_{N_t}$ is the N_t-point inverse fast Fourier transform (IFFT) matrix whose *(m,n)st* entry is given by $N_t^{-1/2} \exp(j2\pi(m-1)(n-1)/N_t)$. Notice that this LCP matrix amounts to phase-rotating each entry of the symbol vector **s**, and then modulating in a digital multicarrier fashion that is

CoC at 6 (highlighting added). As can be seen, the '230 specification—in reverse of the claims—first defines an example matrix, $diag(1, \alpha, \ldots, \alpha^{N_t - 1})$, and then states that this matrix "amounts to phase-rotating each entry of the symbol vector ***s***."

117. In my opinion, one of skill would not be able to reconcile the clear inconsistency between requiring phase "rotation" on the one hand, and the only exemplary

diagonal matrix including a "1" entry on the other. Further, because the specification and the claims take the relevant terms—i.e., the exemplary *diag(1*, α,…, α^{N_t-1}) matrix, and the requirement that the matrix phase rotate each entry of the symbol vector—in reverse order, one of skill would not be able to identify which of the two terms is incorrectly stated. It is thus my opinion that a person of ordinary skill in the art would not be able to determine with reasonable certainty what mathematical operations fall within the scope of any of these claims (*e.g.*, 30, 31, 64, 66, 68, 70) and which do not.

118. I note that Plaintiff's construction of the "diagonal matrix" term seeks to add the requirement that the matrix "modify the phase of at least some," but not all, of the symbol vector entries. I have reviewed the specification and saw no express disclaimer requiring the claimed diagonal matrix to modify the phase of "at least some of" the symbols. Instead, I understand that Plaintiff's argument is based on the fact that the exemplary matrix includes a "1" value. Accordingly, I understand that the parties agree that multiplication by a "1" does not result in a phase rotation. Nevertheless, I disagree with Plaintiff's construction of this term, as Plaintiff plainly attempts to rewrite the plain language of the term—from rotating "each entry," to rotating "at least some" but not all entries.

119. Finally, to the extent that it is argued and the Court finds that multiplication by "1" is a phase rotation as that term is used in the '230 patent—which I dispute—I note that the result of such a construction would be that a matrix of *diag(1*, *1*, …, *1*) would meet this claim term as a result. That is, if a "1" entry is understood to phase rotate one entry of the symbol vector, a series of "1" entries must be understood to phase rotate "each entry"

the symbol vector. In fact, under this construction, any conceivable diagonal matrix—made up of any combination of real and/or complex numbers—would meet this "phase rotation" requirement for the same reasons. In my opinion, one of skill would understand that this result follows from the plain language of the claims, and nothing in the patent specification supports a different result.

H. "subcarriers carry different linear combinations of the information symbols" ('230 cls. 2, 17)

Defendants Construction	Plaintiff Construction
"subcarriers carry different linear combinations of the stream of information symbols transformed by the second encoder"	"the different subcarriers carry different weighted sums of the stream of information symbols transformed by the second encoder"

120. It is my opinion that a person of ordinary skill in the art at the time of the patents would not equate linear combinations and weighted sums. As I explained in Section IV.B above, a weighted sum can be the result of either a linear *or* non-linear combination. Thus, Plaintiff's construction broadens this term to encompass systems that perform non-linear transformations. A person of ordinary skill in the art would not understand such non-linear transformations to fall within the scope of the claim.

V. Disputed Claim Terms for the Carrier Frequency Offset Patents ('309, '185, and '317 Patents) (Collectively, "CFO Patents")[20]

121. In the discussion that follows, each term is presented below along with my understanding of the positions being articulated by the parties and the claim from among the asserted claims in which the term appears.

A. Background

122. Transmitters and receivers of wireless signals use oscillators to send and receive wireless communications. An oscillator is a circuit that produces a stable frequency for wireless transmission; it can be thought of as a kind of clock. Just as it is critical that we synchronize our watches so that we don't miss a flight, it is important that the oscillators of a transmitter and receiver operate at the same frequencies (and even the same phases, much like synchronizing the second hands on two watches) so that the received signal is accurately decoded. For communication schemes sending and receiving many densely packed symbols, like orthogonal frequency division multiplexing (OFDM) contemplated by the CFO Patents, a mismatch between oscillators is "carrier frequency offset" (CFO) that can make it impossible to decode the received signal. To avoid this, receivers can first identify the amount of the offset, and then adjust the signal to compensate for the offset.

[20] I understand that Plaintiff is currently asserting claims 1 and 15 of the '317 patent, claims 9-11 of the '185 patent, and claims 13, 16, 17, 19, and 22-24 of the '309 patent.

B. "null subcarrier" (CFO Patents, all asserted claims)

Defendants' Construction	Plaintiff's Construction
A *subcarrier* on which no value is intended to be transmitted during a specific time period, used to estimate carrier frequency offset	A *subcarrier* on which no value is intended to be transmitted during a specific time period

123. It is my opinion that in view of the CFO Patents specification and file history, a person of ordinary skill in the art would understand "null subcarrier" as "a subcarrier on which no value is intended to be transmitted during a specific time period, used to estimate carrier frequency offset."[21]

124. Conversely, a person of skill in the art would not understand "null subcarrier" to include all subcarriers "on which no value is intended to be transmitted during a specific time period." This is because the specification of the CFO Patents expressly states that not all zero symbols are defined as "null subcarriers," and the invention described in the CFO Patents requires specific hopping and de-hopping zero symbols that are defined as null subcarriers and that are specifically used to estimate carrier frequency offset.

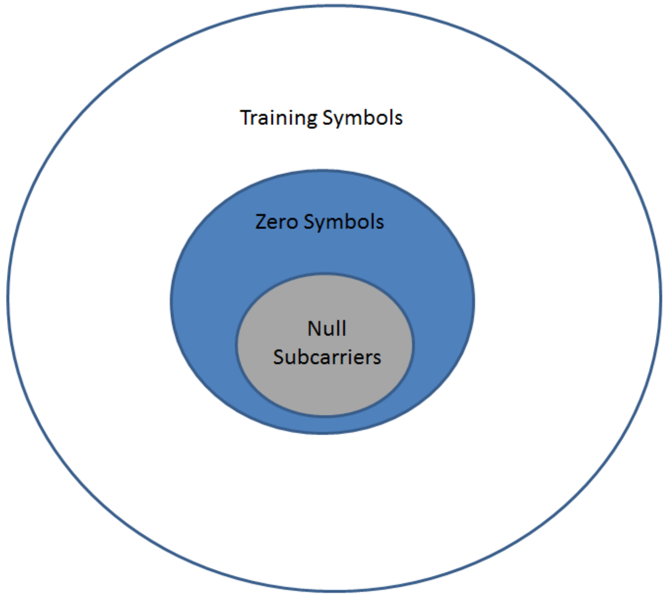
125. Null values, or zero values, are used in transmissions for a number of purposes, including CFO estimation and to remove channel interference. Consistent with this understanding, the CFO Patents describe symbols with zero value used in different ways, including for CFO estimation and to remove channel interference. For example, the

[21] My discussion of constellations and CFO with respect to the "forming . . ." term, below, are also relevant here.

CFO Patents state that "[i]n each OFDM transmission block, there are . . . **4 zero symbols to remove interference from other channels,** and **one zero symbol serving as a null subcarrier**." CFO Specification[22] at 15:64-67 (emphasis added). The CFO Patents also describe that the "one zero symbol serving as a null subcarrier" is used for CFO estimation. CFO Specification at 8:35-38 ("The null subcarrier is inserted so that the position of the null subcarrier hops from block to block and **enables CFO estimation to be separated from MIMO channel estimation**."). Thus, consistent with my opinion of how one of skill understands how zero symbols are used in wireless communications, the patents describe different zero symbols used for different purposes. However, the CFO patents consistently call only the zero symbols used to estimate carrier frequency offset, "null subcarriers." CFO Specification at 15:64-67. In other words, using the terminology of the CFO Patents, one of skill would distinguish a subcarrier that has no value, which could be a zero symbol used to remove interference, and the special case of the null subcarrier, which according to the patent is only used to estimate carrier frequency offset.

126. One of skill would thus understand the CFO Patents' teaching that null subcarriers are a subset of zero symbols, which are a subset of training symbols. This understanding is illustrated in the following Venn diagram.

[22] Because the CFO Patents have the same specification, I refer to the CFO Patents' specifications as "CFO Specification" and provide citations, where applicable, to the column and lines of the '317 patent.



127. Moreover, this distinction is necessary for the invention because the zero symbols and null subcarriers serve different purposes. Specifically, the CFO Patents provide an example and explain that there are five zero value training symbols in each block, but only one is hopped and de-hopped to perform CFO estimation–this is the null subcarrier. CFO Specification at 15:64-67. The invention functions by inserting null subcarriers into a set of blocks by using a hopping code, transmitting the blocks, applying a de-hopping code at the receiver to align the null subcarriers, and then applying a "cost function" to measure the amount of shift in the null space caused by CFO. CFO Specification at 7:53-10:35, 13:23-14:18. Thus, only the location of the "null subcarriers," and **not** the location of all zero value training symbols, is important to performing carrier frequency offset. *Id*. Otherwise stated, the claimed invention would not be operable if it did not distinguish between zero value symbols used for CFO estimation, identified in the

patent as null subcarriers, and other zero symbols, because the transmitters and receivers would not know which zero value symbols to hop and de-hop.

128. Furthermore, the distinction is necessary because the different zero value symbols perform their respective functions *at different times*. After CFO estimation, the CFO specification teaches that **null subcarriers are removed and then channel estimation is performed**. CFO Specification at 10:36-54, 14:19-32. Performing CFO estimation independent of channel estimation is one of the disclosed benefits of the claimed invention. CFO Specification at 15:64-67 ("In each OFDM transmission block, there are . . . 4 zero symbols to remove interference from other channels, and one zero symbol serving as a null subcarrier.").

129. Accordingly, a person of ordinary skill in the art at the time of the invention in view of the CFO Specification and CFO Patent file histories would understand "null subcarrier" as a subcarrier on which no value is intended to be transmitted during a specific time period, used to estimate carrier frequency offset. Specifically, in the patent, "null subcarrier" is distinct from other zero value training symbols, because it is hopped, de-hopped, used for CFO estimation, and used at different times.

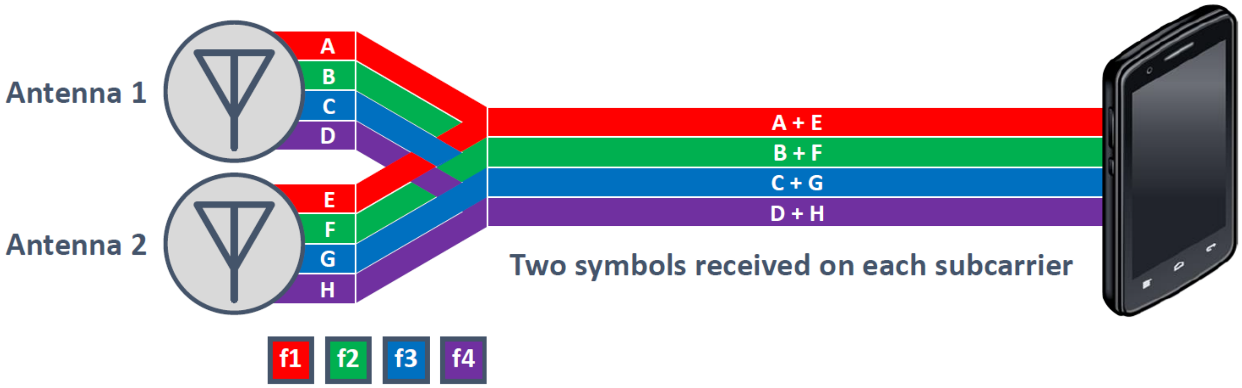
C. "Subcarrier" ('230 patent claims 2, 17; CFO Patents all asserted claims)

Defendants' Construction	Plaintiff's Construction
In a MIMO multi-carrier waveform, one of a number of carrier frequencies within a larger frequency band.	In a multi-carrier waveform, one of a number of carrier frequencies within a larger frequency band.

130. It is my opinion that in view of the specification, a person of ordinary skill in the art would understand "subcarrier," as used in the context of the patents, to mean "in a MIMO multi-carrier waveform, one of a number of carrier frequencies within a larger frequency band." Any construction that lacks "MIMO" is incorrect in view of the CFO specification, because MIMO is essential to the invention and the entire CFO specification is directed to MIMO transmission.

131. The CFO Patents specifically distinguished the invention from prior art SISO (single input single output) techniques (*e.g.*, Ma et al.), and even noted that how to address CFO in SISO systems was known. CFO Specification at 1:40-67. The "subcarriers" in the claims, therefore, must be limited to MIMO as distinguished from the prior art SISO systems.

132. As discussed above, in a MIMO system, the data stream to be sent is separated into different, independent signals, which are sent through an array of antennas at the transmitter and subsequently travel through many paths in space to reach the array of antennas at the receiver. These signals, after transmission and detection, are recombined by the receiver into a single stream. The described process is generally shown in the following figure.



133. Thus, upon reception and compensation for channel effects, reassembly of the different, independent signals is performed, and the data stream is reproduced. In a single-output transmitter, on the other hand, the transmitted signal does not combine with any other different, independent transmitted signals because only one signal is sent, even if it is emitted from more than one antenna. Thus, the enhanced data capacity due to multiple transmitted signals–a hallmark of MIMO–is necessary to the invention of the CFO Patents. In the SISO (prior art) case, it is only necessary to view the single transmission to determine that content. In MIMO, as mentioned above, **all** the transmitted signals must be analyzed to determine the cumulative signal content.

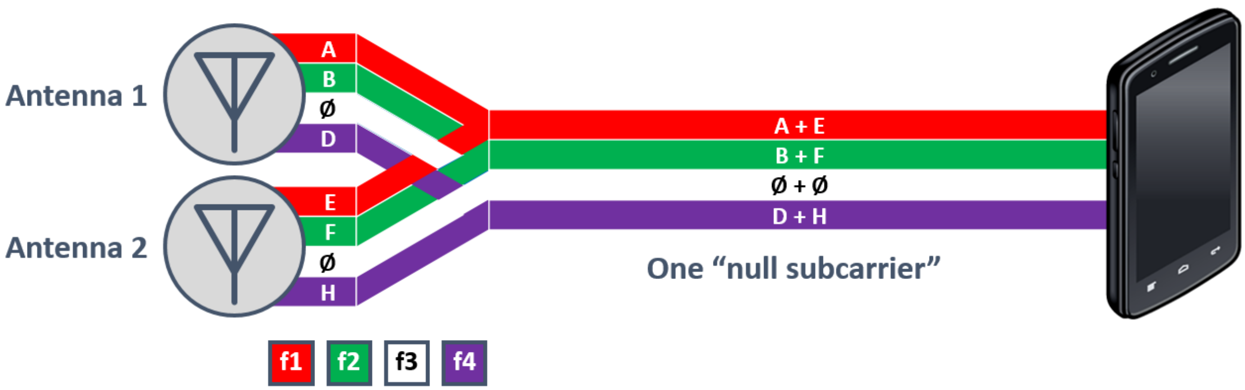
134. Plaintiff's construction contemplates a scenario in which a null subcarrier can be sent on one antenna and a non-null symbol may be sent on another antenna at the same time and frequency. One of skill understands that allowing a "null subcarrier" to be *non-null* on any antenna would make the disclosed CFO estimation technique inoperable. In particular, if one or more antennas of a transmitter were to send a transmission on a subcarrier that were *not* null, the transmitter's combined waveform for that subcarrier would, in turn, be non-null. For example, if a 0 is combined with a 0, the resulting signal

is 0 (i.e., a null subcarrier). On the other hand, if a 0 is combined with a non-zero symbol, X, the resulting waveform is not a null subcarrier, but rather has a value dependent on X.

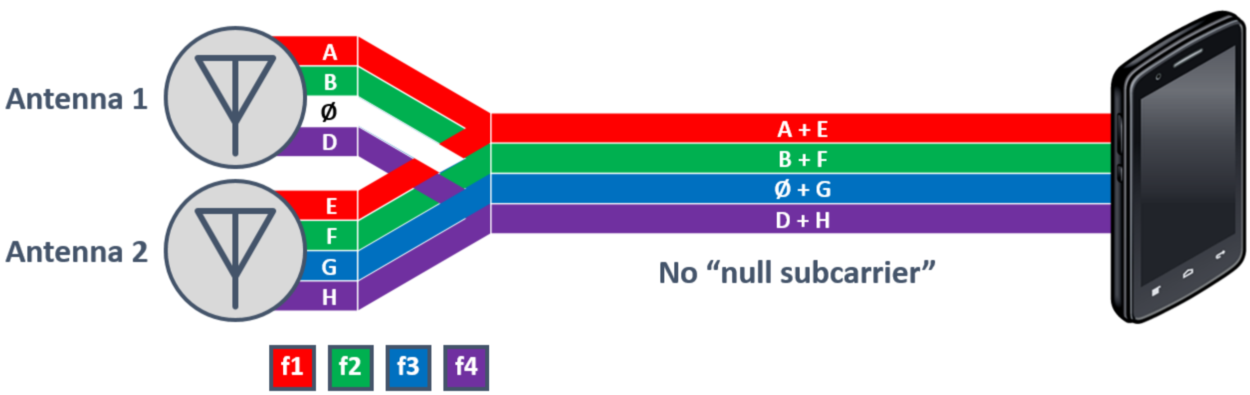
135. Thus, for that subcarrier, the receiver would receive a signal that was not null. This would prevent the receiver from detecting power shifted into the null space because the cost function would never achieve "zero in the absence of noise," which is what the CFO Patents require for CFO estimation. '317 patent at 9:37-39, 9:55-67:

> Consequently, if $\omega=\omega_o$, then $D_N(\omega_o-\omega)=I_N$. Next, recall that the matrix $F_N{}^H T_{zp}$ is orthogonal to $\{f_N(2\Pi n/N)\}_{n=K}{}^{N-1}$. Therefore, if $\omega=\omega_o$, the cost function $J(\omega_o)$ is zero in the absence of noise. However, for this to be true, ω_o must be the unique minimum of $J(\omega)$. ω_o is the unique zero of $J(\omega)$ if
>
> $$\sum_{v=1}^{N_r} E[g(k)g^H(k)]$$
>
> has full rank as established in Proposition 1 below.

136. The illustration below shows a MIMO system where zero symbols are transmitted simultaneously from both antennas on the same subcarrier. In this case, the purple or green adjacent subcarriers may have symbols that are frequency offset into the null subcarrier (f3). According to the invention, this frequency offset can be estimated and corrected through a cost function cited by the CFO patents. This cost function requires that the value of the null space, which in the below figure is represented by f3 (white), be zero.



137. In a situation where only one of the subcarriers on the two streams was nulled, the invention would not function as described because the transmitter's combined waveform on frequency 3 would not be null. As a result, one of skill would understand that the cost function described in the CFO Patents could not accurately estimate the frequency offset.



138. Moreover, one of skill appreciates that the limitation to MIMO is expressed throughout the CFO Patent, including the title ("Estimating Frequency-Offsets and Multi-Antenna Channels in MIMO OFDM Systems"), abstract ("Techniques are described for carrier frequency offset (CFO) and channel estimation of orthogonal frequency division multiplexing (OFDM) transmissions over multiple-input multiple-output (MIMO) frequency-selective fading channels. …"), summary of the invention ("SUMMARY in

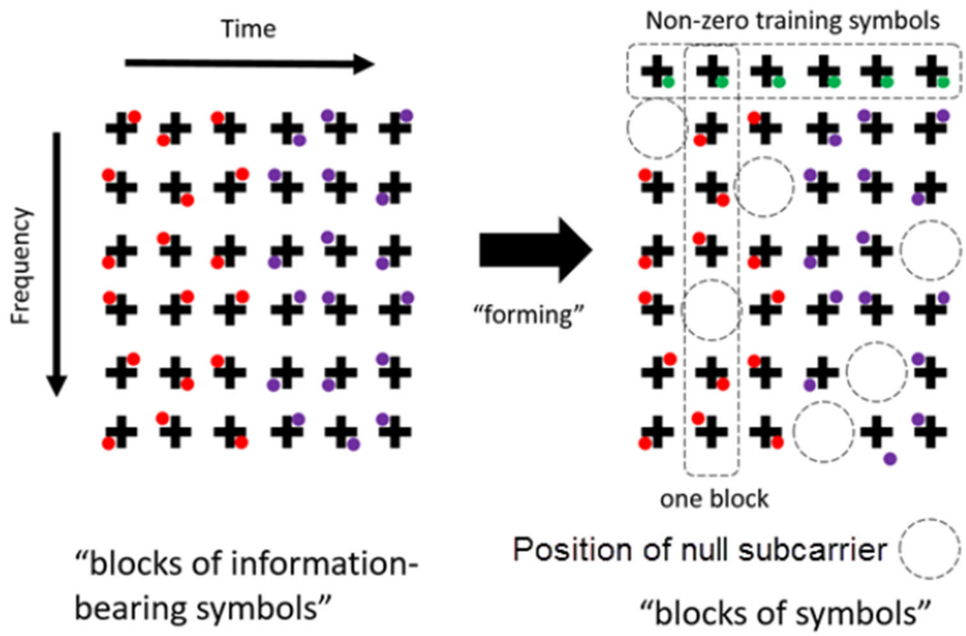
general, the invention is directed to techniques for carrier frequency offset (CFO) and channel estimation of orthogonal frequency division multiplexing (OFDM) transmissions over multiple-input multiple-output (MIMO) frequency-selective fading channels. …), the discussion regarding the problem the CFO Patents allegedly solve ("However, MIMO OFDM systems have increasing channel estimation complexity as the number of antennas increases due to the increased number of unknowns which must be estimated and have great sensitivity to carrier frequency off sets (CFO)"), and figures. *See*, *e.g.*, CFO Specification at Title, Abstract, 2:16-20, Figs. 1-12. For example, the CFO Patents describe that the number of zero symbols that are added for CFO estimation is equal to the number of transmit antennas. In other words, the CFO Patents describe, as illustrated above, that null subcarriers are transmitted from *each* of the transmit antennas so that the invention can function as described. CFO Specification at 5:32-37.

D. "form … blocks of symbols/output symbols of symbols/output symbols" "forming blocks of symbols/output symbols" (CFO Patents, all asserted claims)

Defendants' Construction	Plaintiff's Construction
Generating blocks of symbols for transmission at consecutive times	The terms "form" and "forming" do not require construction. The jury can apply the ordinary meaning of those terms.

139. It is my opinion that in view of the CFO Patents, a person of ordinary skill in the art would understand the "forming" terms to mean "generating blocks of symbols for transmission at consecutive times." This term has a specific meaning in the context of the CFO patents because the disclosed "forming" of blocks is required for invention of the CFO Patents to function. Specifically, the invention requires inserting training symbols **in**

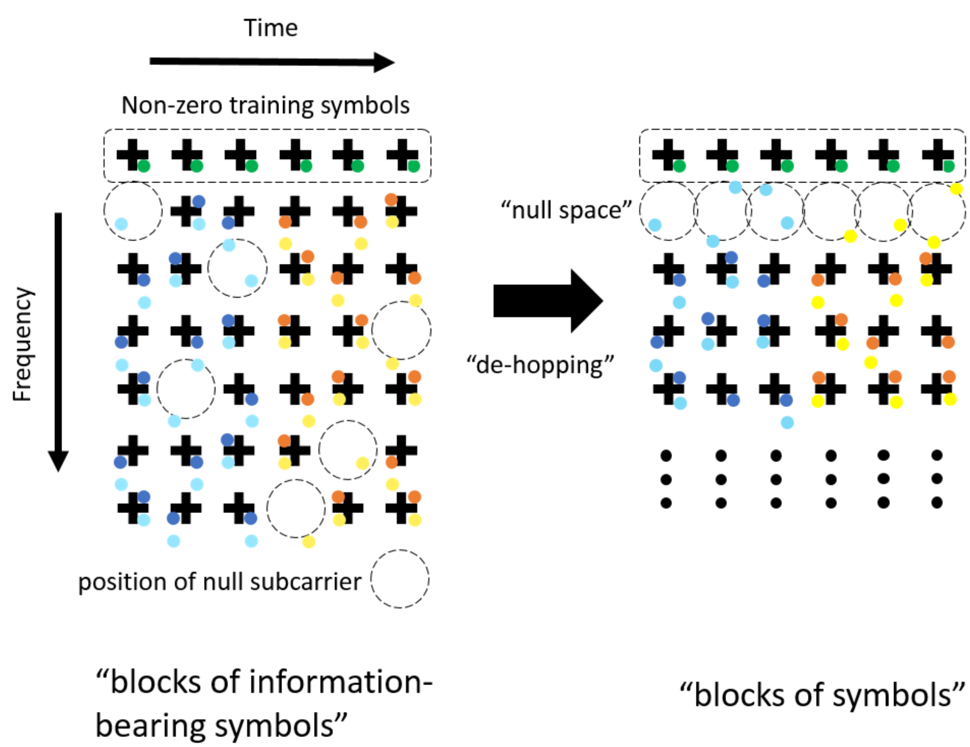
each (consecutive) block. *See*, *e.g.*, CFO Specification at 16:15-19; also note p. 2509 in Ma et al. Thus, "forming" means generating blocks of symbols for transmission consecutively, consistent with the following figure.



140. As illustrated in the figure above (right), the CFO Patents likewise teach that the claimed invention requires training symbols in every block, which are taught as both zero and non-zero symbols. For example, the CFO Patents explain that "[f]or the presently described techniques, one non-zero training symbol and one zero training symbol **for each block are used** . . . ." CFO Specification at 16:26-29. In other words, for the claimed system (the presently described techniques), one null subcarrier is used ***for each block***. Importantly, this statement was made in distinguishing the claimed system over a similar system by M. Morelli and U. Mengali that was supposedly less efficient because it required 8 identical parts instead of just using (at least) one null subcarrier for each block in the claimed system.

141. Moreover, not only do the CFO Patents state that there is at least one null subcarrier in every block, but the only CFO estimation disclosed in the CFO Patents ***requires*** null subcarriers in each block. At a high level, a "cost function" is computed across the de-hopped, hence aligned, null subcarriers for ***each*** block and if one block lacked a null subcarrier, one of skill would appreciate that the cost function would not be able to estimate the CFO because it would be corrupted with data symbols or training symbols.

142. More specifically, the CFO Patents repeatedly describe inserting a null subcarrier at different "positions," or "hopping," within each block by using a hopping code before transmission, as is shown by the figure above. After transmission, the receiving station applies a de-hopping code such that all the inserted null subcarriers are aligned at one frequency; this is called a "null space," as shown in the figure below.



143. Then, the receiver runs a "cost function" to determine whether any non-zero values are in the null space. As explained in the earlier publications including by the named inventors, which applied the same CFO estimation techniques, the cost function, j(ω), can be viewed as "measuring the energy falling into the subbands corresponding to the set of null subcarriers, [1] used J(ω) to derive adaptive CFO estimation algorithms (see also Section V)." Ma et al. p. 2507 footnote 1.[23] Accordingly, one of skill appreciates that the invention will be inoperable without a null subcarrier in each block because it could never estimate CFO as it cannot distinguish energy (or symbols) in the null space caused by CFO and energy (or symbols) from blocks that lack null subcarriers.

144. Furthermore, as explained in Ma et al. and the CFO Specification, the hopping code is dependent on the block index, k. In fact, Ma et al. (p. 2509) explains that "[t]he idea behind null subcarrier hopping is to make T_{sc} dependent on the block index."[24] Thus, there must be a null subcarrier in each consecutive block.

E. "block length" ('317 patent, cls. 1 and 19)

Defendants' Construction	Plaintiff's Construction
The number of subcarriers in a block of symbols	number of symbols in a block

[23] Ma et al. provides detailed analysis of the underlying mathematics, *e.g.*, p. 2507.

[24] T_{sc} is the hopping code (subcarrier insertion) matrix, or "permutation matrix." 8:59.

“position” or “positions” (CFO Patents, all asserted claims)

Defendants’ Construction	Plaintiff’s Construction
Frequency range	The location of a symbol in a block of symbols

145. “Position[s]” and “block length” are related terms because they refer to the general structure of OFDM block transmissions.

146. I understand that the parties agree that “blocks of symbols” refers to “a group of symbols for transmission at a given time” and that subcarrier is a “frequency range.”

147. It is my opinion that in view of the specification, a person of ordinary skill in the art at the time of the invention would understand “block length” as “the number of subcarriers in a block of symbols” and “position[s]” as “frequency range.” These constructions are consistent with both the CFO Patents and industry usage.

148. With regard to “block length,” the CFO Specification defines “N” as the variable depicting “block length,” and “N” is defined as the number of subcarriers in a block. The CFO Specification states that “FIGS. 5-12 are graphs that present simulations of OFDM transmissions over MIMO frequency-selective channels *using the described techniques for estimating CFO, channel and phase noise*.” CFO Specification at 14:33-36. In describing such simulations, the specification explains that “[t]he OFDM block length is designed as N=64 as in HIPERLAN/2.” *Id.* at 15:26-32. In HIPERLAN/2, block length is the number of subcarriers. Thus, when the CFO Specification states that “[t]he OFDM block length is designed as N=64 as in HIPERLAN/2,” it is referring to 64

subcarriers. *See* Feuersanger at 1-3; HIPERLAN/2 Specification. HIPERLAN/2 ("High Performance Local Area Network") is simply another standard for wireless transmission.

149. Likewise, in describing the formation of the claimed "blocks of symbols" (referred to throughout as $\bar{u}_{\mu}(k)$), the CFO Specification explains that "[e]ach of training symbol insertion units 15 inserts two or more training symbols, which may have non-zero or zero values, within space-time encoded blocks $\{c\mu(k)\}_{\mu=1}^{N\,t}$ 14 and applies a hopping code to blocks $\{c\mu(k)\}_{\mu=1}^{N\,t}$ 14 to form a ***vectors $\bar{u}_{\mu}(k)$ 16 with length N*** for the µth antenna of multi-antenna transmitter 4." '317 patent at 5:32-37 (emphasis added).

150. Moreover, the specification explains that "N" corresponds to a number of subcarriers, not merely a number of symbols. *Id.* at 14:39-45 ("Similarly, the signal-to-noise ratio (SNR) versus CRLB decreases as the number of blocks increases. If N>>N−K, ***i.e., the number of subcarriers*** is much greater than the number of null subcarriers, $T_{zp} \approx I_N$."). Thus, it is undisputed that the specification explicitly defines "block length" as N and defines "N" as the number of subcarriers in a block. N is the expanded block length, including the zeros; K is the original block length (Ma et al. reinforces this).

151. With regard to "position," one of skill appreciates that "frequency range" is most consistent with the CFO Specification and intrinsic record.

152. The CFO Specification describes the channel estimation and CFO mitigation techniques of the prior art by explaining that "[i]n the IEEE 802.11a, IEEE 802.11g, and HIPERLAN/2 standards, sparsely placed pilot symbols are present in every OFDM symbol and pilot symbols are placed in the same positions from block to block." *See* '317 patent

at 1:60-64. In each of those systems, the "positions" within block length "N" correspond to specific carrier frequency ranges. *See* Feuersanger at 1-3; HIPERLAN/2 Specification.

153. Similarly, in describing the claimed system, the CFO Provisional describes that the "position" of training symbols is fixed from block to block as depicted in Fig. 2. CFO Provisional at 3. In Figure 2 of the CFO Provisional, reproduced above, over time, the "position" of the training symbols changes along the frequency domain.

154. During prosecution of the parent application to the CFO Patents, applicants also explained the meaning of "position." Specifically, applicants described the prior art at issue (US 2004/0166887 – "Laroia") as follows: "[t]he pilots change their positions, or "hop," over time for various reasons such as frequency diversity." 10/850,961 FH, Resp. to Sept. 30, 2010 OA at 14. Figure 8 from Laroia makes clear that over time, the disclosed pilots occur at different positions, i.e., frequency ranges.

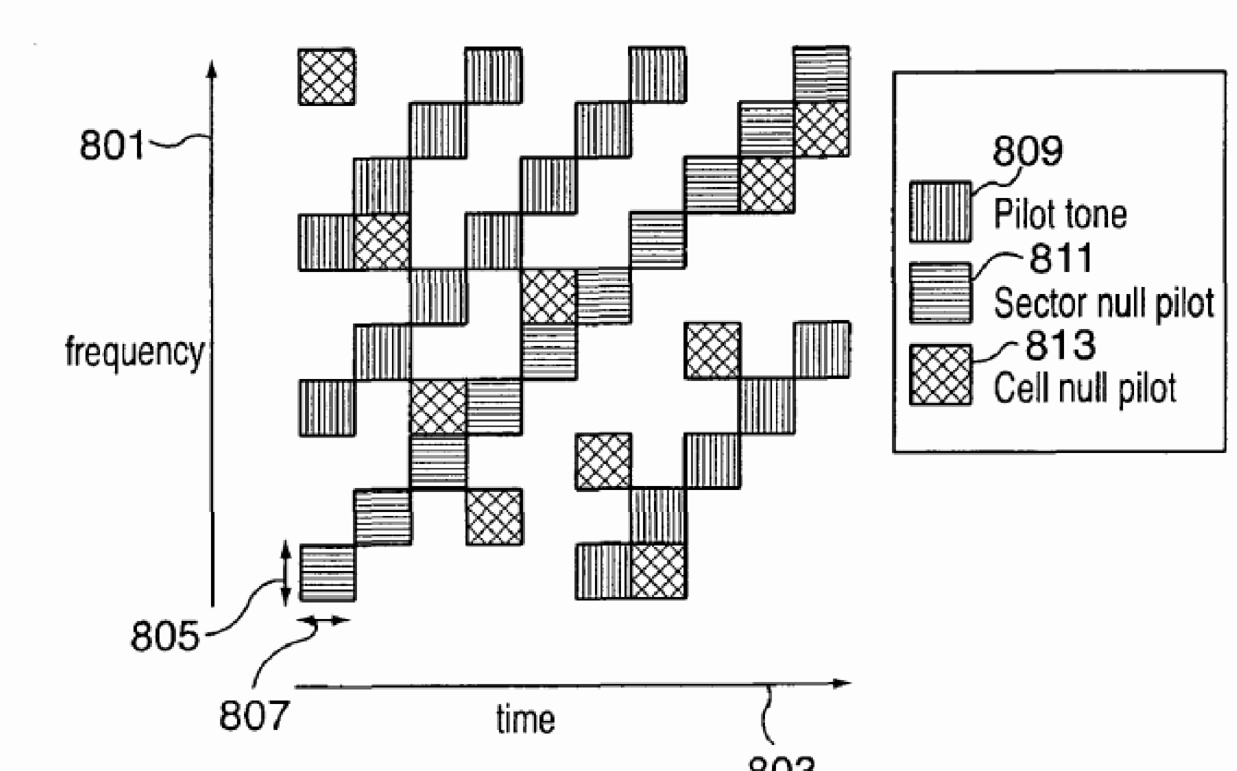


FIG. 8

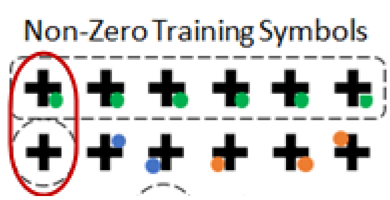
155. Moreover, substituting "location" for "position" provides no guidance to the Court or to one of ordinary skill in the art.

F. "inserting at least one training symbol adjacent to at least one null subcarrier" ('185 patent, cl. 6, 15 and '309 patent, cls. 5, 19)

Defendants' Construction	Plaintiff's Construction
Inserting, within a block, at least one training symbol at an adjacent frequency to at least one null subcarrier	inserting at least one training symbol adjacent to at least one null subcarrier: placing at least one training symbol next to at least one null subcarrier

156. It is my opinion that in view of the specification, a person of ordinary skill in the art would understand "inserting at least one training symbol adjacent to at least one null subcarrier" as "inserting, within a block, at least one training symbol at an adjacent frequency to at least one null subcarrier."

157. While the CFO Specification never explicitly explains "adjacent to," it is clear from the context of CFO Specification that it must be adjacent in frequency because blocks are read out in time. As explained above, and exemplified in Figure 3, blocks are only one symbol wide, so one of skill understands that the only possible adjacency could be in the frequency dimension. Otherwise stated, "adjacent" cannot be "adjacent in time." I illustrated this point in figures above; an excerpt of my opinion is shown below, where a null subcarrier is shown adjacent (in frequency) to a training symbol, both symbols encircled in red:



158. This understanding is reflected in the CFO Patents. For example, in Figures 2 and 3 show that blocks are one-dimensional vectors,[25] so there is only one possible meaning for "adjacent" – that the at least one training symbol and at least one null subcarrier are placed in subcarrier frequency ranges next to each other.

[25] By one-dimensional vector I mean that each block is comprised of one symbol (a data value or a zero value) per subcarrier (the width, or time), by the number of subcarriers in the block (the length).

159. In my opinion, one of ordinary skill in the art would not understand Plaintiff's construction because "inserting" does not mean "placing," particularly in this context. When discussing vectors, which is the context of inserting a training symbol next to another training symbol as discussed in the CFO Patents, the terms inserting and placing are not synonymous. "Placing" means putting a new value into the vector where an old value may have existed, and therefore overwriting and replacing that older value. "Inserting," on the other hand, does not overwrite any previous values and instead merely inserts a new value between two existing values, analogous to word processing, where inserting text does not mean overwriting the existing text. Each value in the vector remains in that vector after the insertion, with the caveat that the new value is inserted in a particular location.

G. "training symbol" (CFO Patents, all asserted claims)

Defendants' Construction	Plaintiff's Construction
"symbol with a predefined value that can be used by the device that receives the symbol to determine a physical characteristic of the transmitted signals"	"In a transmission system, a symbol having a predefined value that is transmitted by the transmitter to enable a receiver to determine a parameter that can be used to decode other transmitted

160. In my opinion, a person of ordinary skill in the art would understand "training symbols" at the time of the invention in view of the specification as symbols to be used for "determining characteristics of the transmitted signal."

161. The CFO Specification consistently describes using training symbols to determine a physical characteristic of the transmitted signal. *See*, *e.g.*, '317 patent at 2:16-

3:26; 4:22-47; 14:9-32; 15:60-16:9; (describing using training symbols to determine CFO and channel interference); 7:37-52; 8:32-51; 16:22-54; (estimating CFO); 12:48-60 (using training symbols to estimate phase noise); 17:1-12 (using training symbols to estimate CFO, channel interference, and phase noise).

162. A person of ordinary skill in the art at the time of the invention would not understand the CFO Specification to limit training symbols to solely determine parameters that can be used to decode other transmitted symbols. As cited above, the CFO Specification discloses using "training symbols" to determine physical characteristics of the transmitted signals: CFO, channel interference, and phase noise. In fact, there is no teaching anywhere in the CFO Specification that limits training symbols to being used to enable a receiver to determine a parameter that can be used to decode other transmitted symbols.

163. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct, and that this disclosure was executed on November 3, 2021, at Madison, WI.

Daniel van der Weide, Ph.D.